

Introduction to Nervous Tissue

I. Organization of the Nervous System (pp. 388–389; Marieb Figs. 11.1–11.2)

- A. The central nervous system consists of the brain and spinal cord, and is the integrating and command center of the nervous system (p. 388; Marieb Figs. 11.1–11.2).
- B. The peripheral nervous system is outside the central nervous system (pp. 388–389; Marieb Fig. 11.2).
 - 1. The sensory, or afferent, division of the peripheral nervous system carries impulses toward the central nervous system from sensory receptors located throughout the body.
 - 2. The motor, or efferent, division of the peripheral nervous system carries impulses from the central nervous system to effector organs, which are muscles and glands.
 - a. The somatic nervous system consists of somatic nerve fibers that conduct impulses from the CNS to skeletal muscles, and allow conscious control of motor activities.
 - b. The autonomic nervous system is an involuntary system consisting of visceral motor nerve fibers that regulate the activity of smooth muscle, cardiac muscle, and glands.

II. Histology of Nervous Tissue (pp. 389–397; Marieb Figs. 11.3–11.5; Marieb Table 11.1)

- A. Neuroglia, or glial cells, are closely associated with neurons, providing a protective and supportive network (pp. 389–391; Marieb Fig. 11.3).
 - 1. Astrocytes are glial cells of the CNS that regulate the chemical environment around neurons and exchange between neurons and capillaries.
 - 2. Microglia are glial cells of the CNS that monitor health and perform defense functions for neurons.
 - 3. Ependymal cells are glial cells of the CNS that line the central cavities of the brain and spinal cord and help circulate cerebrospinal fluid.
 - 4. Oligodendrocytes are glial cells of the CNS that wrap around neuron fibers, forming myelin sheaths.
 - 5. Satellite cells are glial cells of the PNS whose function is largely unknown. They are found surrounding neuron cell bodies within ganglia.
 - 6. Schwann cells, or neurolemmocytes, are glial cells of the PNS that surround nerve fibers, forming the myelin sheath.
- B. Neurons are specialized cells that conduct messages in the form of electrical impulses throughout the body (pp. 391–397; Marieb Figs. 11.4–11.5; Marieb Table 11.1).
 - 1. Neurons function optimally for a lifetime, are mostly amitotic, and have an exceptionally high metabolic rate requiring oxygen and glucose.
 - a. The neuron cell body is the major biosynthetic center containing the usual organelles.
 - b. Dendrites are cell processes that are the receptive regions of the cell.
 - c. Each neuron has a single axon that generates and conducts nerve impulses away from the cell body to the axon terminals.
 - d. The myelin sheath is a whitish, fatty, segmented covering that protects, insulates, and increases conduction velocity of axons.
 - 2. There are three structural classes of neurons.

- a. Multipolar neurons have three or more processes.
 - b. Bipolar neurons have a single axon and dendrite.
 - c. Unipolar neurons have a single process extending from the cell body that is associated with receptors at the distal end.
3. There are three functional classes of neurons.
- a. Sensory, or afferent, neurons conduct impulses toward the CNS from receptors.
 - b. Motor, or efferent, neurons conduct impulses from the CNS to effectors.
 - c. Interneurons, or association neurons, conduct impulses between sensory and motor neurons, or in CNS integration pathways.

III. Neurophysiology (pp. 397–421; Marieb Figs. 11.6–11.22; Marieb Tables 11.2–11.3)

- A. Basic Principles of Electricity (pp. 397–398)
- 1. Voltage is a measure of the amount of difference in electrical charge between two points, called the potential difference.
 - 2. The flow of electrical charge from point to point is called current, and is dependent on voltage and resistance (hindrance to current flow).
 - 3. In the body, electrical currents are due to the movement of ions across cellular membranes.
- B. The Role of Membrane Ion Channels (pp. 393–399; Marieb Fig. 11.6)
- 1. The cell has many gated ion channels.
 - a. Ligand-gated channels open when the appropriate chemical (the ligand) binds.
 - b. Voltage-gated channels open in response to a change in membrane potential.
 - 2. When ion channels are open, ions diffuse across the membrane, creating electrical currents.
- C. The Resting Membrane Potential (pp. 399–400; Marieb Figs. 11.7–11.8)
- 1. The neuron cell membrane is polarized, being more negatively charged inside than outside. The degree of this difference in electrical charge is the resting membrane potential.
 - 2. The resting membrane potential is generated by differences in ionic makeup of intracellular and extracellular fluids, and differential membrane permeability to solutes.
- D. Membrane Potentials That Act as Signals (pp. 400–409; Marieb Figs. 11.9–11.17)
- 1. Neurons use changes in membrane potential as communication signals. These can be brought on by changes in membrane permeability to any ion, or alteration of ion concentrations on the two sides of the membrane.
 - 2. Changes in membrane potential relative to resting membrane potential can either be depolarizations, in which the interior of the cell becomes less negative, or hyperpolarizations, in which the interior of the cell becomes more negatively charged.
 - 3. Graded potentials are short-lived, local changes in membrane potentials. They can either be depolarizations or hyperpolarizations, and are critical to the generation of action potentials.
 - 4. Action potentials, or nerve impulses, occur on axons and are the principle way neurons communicate.
 - a. Generation of an action potential involves a transient increase in Na^+ permeability, followed by restoration of Na^+ impermeability, and then a short-lived increase in K^+ permeability.
 - b. Propagation, or transmission, of an action potential occurs as the local currents of an area undergoing depolarization cause depolarization of the forward adjacent area.
 - c. Repolarization, which restores resting membrane potential, follows depolarization along the membrane.

5. A critical minimum, or threshold, depolarization is defined by the amount of influx of Na^+ that at least equals the amount of efflux of K^+ .
 6. Action potentials are an all-or-none phenomena: they either happen completely, in the case of a threshold stimulus, or not at all, in the event of a subthreshold stimulus.
 7. Stimulus intensity is coded in the frequency of action potentials.
 8. The refractory period of an axon is related to the period of time required so that a neuron can generate another action potential.
- E. Influence of Axon Diameter and the Myelin Sheath on Conduction Velocity (p. 407; Marieb Fig. 11.16)
1. Axons with larger diameters conduct impulses faster than axons with smaller diameters.
 2. Unmyelinated axons conduct impulses relatively slowly, while myelinated axons have a high conduction velocity.
- F. The Synapse (pp. 408–411; Marieb Figs. 11.17–11.18)
1. A synapse is a junction that mediates information transfer between neurons or between a neuron and an effector cell.
 2. Neurons conducting impulses toward the synapse are presynaptic cells, and neurons carrying impulses away from the synapse are postsynaptic cells.
 3. Chemical synapses are specialized for release and reception of chemical neurotransmitters.
- G. Postsynaptic Potentials and Synaptic Integration (pp. 411–413; Marieb Figs. 11.19– 11.20; Marieb Table 11.2)
1. Neurotransmitters mediate graded potentials on the postsynaptic cell that may be excitatory or inhibitory.
 2. Summation by the postsynaptic neuron is accomplished in two ways: temporal summation, which occurs in response to several successive releases of neurotransmitter, and spatial summation, which occurs when the postsynaptic cell is stimulated at the same time by multiple terminals.
 3. Synaptic potentiation results when a presynaptic cell is stimulated repeatedly or continuously, resulting in an enhanced release of neurotransmitter.
 4. Presynaptic inhibition results when another neuron inhibits the release of excitatory neurotransmitter from a presynaptic cell.
- H. Neurotransmitters and Their Receptors (pp. 413–421; Marieb Figs. 11.21–11.22; Marieb Table 11.3)
1. Neurotransmitters are one of the ways neurons communicate, and they have several chemical classes.
 2. Functional classifications of neurotransmitters consider whether the effects are excitatory or inhibitory, and whether the effects are direct or indirect.

Central Nervous System

I. The Brain (pp. 431–456; Marieb Figs. 12.1–12.19)

- A. Regions and Organization (p. 433; Marieb Fig. 12.4)
 - 1. The basic pattern of the CNS consists of a central cavity surrounded by a gray matter core, external to which is white matter.
 - 2. In the brain, the cerebrum and cerebellum have an outer gray matter layer, which is reduced to scattered gray matter nuclei in the spinal cord.
- B. Ventricles (pp. 433–434; Marieb Fig. 12.5)
 - 1. The ventricles of the brain are continuous with one another, and with the central canal of the spinal cord. They are lined with ependymal cells, and are filled with cerebrospinal fluid.
- C. Cerebral Hemispheres (pp. 434–443; Marieb Figs. 12.6–12.11; Marieb Table 12.1)
 - 1. The cerebral hemispheres form the superior part of the brain, and are characterized by ridges and grooves called gyri and sulci.
 - 2. The cerebral hemispheres are separated along the midline by the longitudinal fissure, and are separated from the cerebellum along the transverse cerebral fissure.
 - 3. The five lobes of the brain separated by specific sulci are: frontal, parietal, temporal, occipital, and insula.
 - 4. The cerebral cortex is the location of the conscious mind, allowing us to communicate, remember, and understand.
 - 5. The cerebral cortex has several motor areas located in the frontal lobes, which control voluntary movement. (Note: the following are examples with which you should be familiar, but not necessarily memorize. Just remember that the motor areas are all located in the frontal lobe.)
 - a. The primary motor cortex allows conscious control of skilled voluntary movement of skeletal muscles.
 - b. The premotor cortex is the region controlling learned motor skills.
 - c. Broca's area is a motor speech area that controls muscles involved in speech production.
 - d. The frontal eye field controls eye movement.
 - 6. There are several sensory areas of the cerebral cortex that occur in the parietal, temporal, and occipital lobes. (Again, just remember some examples of sensory areas and that they are located in the "back half" of the brain.)
 - a. The primary somatosensory cortex allows spatial discrimination and the ability to detect the location of stimulation.
 - b. The somatosensory association cortex integrates sensory information and produces an understanding of the stimulus being felt.
 - c. The primary visual cortex and visual association area allow reception and interpretation of visual stimuli.
 - d. The primary auditory cortex and auditory association area allow detection of the properties and contextual recognition of sound.
 - e. The olfactory cortex allows detection of odors.
 - f. The gustatory cortex allows perception of taste stimuli.
 - g. The vestibular cortex is responsible for conscious awareness of balance.

7. Several association areas are not connected to any sensory cortices.
 - a. The prefrontal cortex is involved with intellect, cognition, recall, and personality, and is closely linked to the limbic system.
 - b. The language areas involved in comprehension and articulation include Wernicke's area, Broca's area, the lateral prefrontal cortex, and the lateral and ventral parts of the temporal lobe.
 - c. The posterior association area receives input from all sensory areas, integrating signals into a single thought.
 - d. The visceral association area is involved in conscious visceral sensation.
8. There is lateralization of cortical functioning, in which each cerebral hemisphere has unique abilities not shared by the other half.
 - a. One hemisphere (often the left) dominates language abilities, math, and logic, and the other hemisphere (often the right) dominates visual-spatial skills, intuition, emotion, and artistic and musical skills.
9. Cerebral white matter is responsible for communication between cerebral areas and the cerebral cortex and lower CNS centers. (Note: see text/notes for information on commissures, projection fibers, and association fibers.)
10. Basal nuclei consist of a group of subcortical nuclei, which play a role in motor control and regulating attention and cognition.
- D. The diencephalon is a set of gray matter areas, and consists of the thalamus, hypothalamus, and epithalamus (pp. 443–447; Marieb Figs. 12.11–12.15; Marieb Table 12.1).
 1. The thalamus plays a key role in mediating sensation, motor activities, cortical arousal, learning, and memory.
 2. The hypothalamus is the control center of the body, regulating ANS activity such as emotional response, body temperature, food intake, sleep-wake cycles, and endocrine function.
 3. The epithalamus includes the pineal gland, which secretes melatonin and regulates the sleep-wake cycle.
- E. The brain stem, consisting of the midbrain, pons, and medulla oblongata, produces rigidly programmed, automatic behaviors necessary for survival (pp. 447–451; Marieb Figs. 12.15–12.16; Marieb Table 12.1).
 1. The midbrain is the pathway to higher brain areas, serves as the link between the cerebellum and the cerebral cortex, houses centers for certain cranial nerves, and contains the corpora quadrigemina which mediates reflexes associated with the head.
 2. The pons contains fiber tracts that complete conduction pathways between the brain and spinal cord.
 3. The medulla oblongata is the location of several visceral centers controlling vital functions such as cardiac and respiratory rate.
- F. Cerebellum (pp. 451–454; Marieb Fig. 12.17; Marieb Table 12.1)
 1. The cerebellum processes inputs from several structures and coordinates skeletal muscle contraction to produce smooth movement.
 2. Cerebellar processing follows a functional scheme in which the frontal cortex communicates the intent to initiate voluntary movement to the cerebellum, the cerebellum collects input concerning balance and tension in muscles and ligaments, and the best way to coordinate muscle activity is relayed back to the cerebral cortex.

III. Protection of the Brain (pp. 463–470; Marieb Figs. 12.24–12.27)

- A. Meninges are three connective tissue membranes that cover and protect the CNS, protect blood vessels and enclose venous sinuses, contain cerebrospinal fluid, and partition the brain (pp. 463–465; Marieb Figs. 12.24–12.25).
 - 1. The dura mater is the most durable, outermost covering that extends inward in certain areas to limit movement of the brain within the cranium.
 - 2. The arachnoid mater is the middle meninx that forms a loose brain covering.
 - 3. The pia mater is the innermost layer that clings tightly to the brain.
- B. Cerebrospinal Fluid (pp. 465–467; Marieb Figs. 12.26–12.27)
 - 1. Cerebrospinal fluid (CSF) is the fluid found within the ventricles of the brain and surrounding the brain and spinal cord.
 - 2. CSF gives buoyancy to the brain, protects the brain and spinal cord from impact damage, and is a delivery medium for nutrients and chemical signals.
- C. The blood-brain barrier is a protective mechanism that helps maintain a protective environment for the brain (p. 467).

IV. The Spinal Cord (pp. 470–481; Marieb Figs. 12.28–12.35; Marieb Tables 12.2–12.3)

- A. Gross Anatomy and Protection (pp. 470–472; Marieb Figs. 12.28–12.29)
 - 1. The spinal cord extends from the foramen magnum of the skull to the level of the first or second lumbar vertebrae. It provides a two-way conduction pathway to and from the brain and serves as a major reflex center.
 - 2. The spinal cord has 31 pairs of spinal nerves along its length that define the segments of the cord.
 - 3. There are cervical and lumbar enlargements for the nerves that serve the limbs, and a collection of nerve roots (cauda equina) that travel through the vertebral column to their intervertebral foramina.
- B. Cross-Sectional Anatomy (pp. 472–478; Marieb Figs. 12.30–12.35; Marieb Tables 12.2–12.3)
 - 1. Two grooves partially divide the spinal cord into two halves: the anterior and posterior median fissures.
 - 2. Two arms that extend posteriorly are dorsal horns, and the two arms that extend anteriorly are ventral horns.
 - 3. In the thoracic and superior lumbar regions, there are also paired lateral horns that extend laterally between the dorsal and ventral horns.
 - 4. Afferent fibers from peripheral receptors form the dorsal roots of the spinal cord.
 - 5. The white matter of the spinal cord allows communication between the cord and brain.

The Peripheral Nervous System and Reflex Activity

PART 1: SENSORY RECEPTORS AND SENSATION

I. Sensory Receptors (pp. 491–494; Marieb Fig. 13.1; Marieb Table 13.1)

- A. Sensory receptors are specialized to respond to changes in their environment called stimuli (pp. 491–494).
 - 1. Receptors may be classified according to the activating stimulus. (Note: these include thermoreceptors, mechanoreceptors, photoreceptors, etc.)
 - 2. Receptors may be classified based on their location or the location of the activating stimulus. (These include exteroceptors, interoceptors, and proprioceptors).

PART 2: TRANSMISSION LINES: NERVES AND THEIR STRUCTURE

I. Nerves and Associated Ganglia (pp. 498–500; Marieb Figs. 13.3–13.4)

- A. A nerve is a cordlike organ consisting of parallel bundles of peripheral axons enclosed by connective tissue wrappings.
- B. Ganglia are collections of neuron cell bodies associated with nerves in the PNS.

II. Cranial Nerves (pp. 500–508; Marieb Fig. 13.5; Marieb Table 13.2)

- A. Olfactory nerves (I) are responsible for smell.
- B. Optic nerves (II) are responsible for vision.
- C. Oculomotor nerves (III) play a role in eye movement.
- D. Trochlear nerves (IV) play a role in eye movement.
- E. Trigeminal nerves (V) are general sensory nerves of the face. There are three divisions called the ophthalmic, maxillary, and mandibular.
- F. Abducens nerves (VI) play a role in eye movement.
- G. Facial nerves (VII) function as the chief motor nerves of the face.
- H. Vestibulocochlear nerves (VIII) are responsible for hearing and equilibrium. There are two branches called the vestibular and the cochlear.
- I. Glossopharyngeal nerves (IX) innervate part of the tongue and pharynx. (Note: the pharynx is essentially the throat. That term will be better defined in A&P2).
- J. Vagus nerves (X) innervate the heart, lungs, and the abdominal organs. Vagus is the only nerve that innervates abdominopelvic structures. (All others just serve head/neck structures.)
- K. Accessory nerves (XI) move structures associated with the head and neck.
- L. Hypoglossal nerves (XII) are mixed nerves that arise from the medulla and serve the tongue.

III. Spinal Nerves (pp. 508–518; Marieb Figs. 13.6–13.12; Marieb Tables 13.3–13.6)

- A. Thirty-one pairs of mixed spinal nerves arise from the spinal cord and serve the entire body except the head and neck.
- B. Innervation of Specific Body Regions

1. Each spinal nerve connects to the spinal cord by a dorsal root and a ventral root.
2. Rami lie distal to and are lateral branches of the spinal nerves that carry both motor and sensory fibers.
3. The back is innervated by the dorsal rami with each rami innervating the muscle in line with the point of origin from the spinal column.
4. Only in the thorax are the ventral rami arranged in a simple segmental pattern corresponding to that of the dorsal rami.
5. The cervical plexus is formed by the ventral rami of the first four cervical nerves.
6. The brachial plexus is situated partly in the neck and partly in the axilla and gives rise to virtually all the nerves that innervate the upper limb.
7. The sacral and lumbar plexuses overlap and because many fibers of the lumbar plexus contribute to the sacral plexus via the lumbosacral trunk, the two plexuses are often referred to as the lumbosacral plexus.

PART 3: REFLEX ACTIVITY

I. The Reflex Arc (pp. 521–522; Marieb Fig. 13.14)

- A. Reflexes are unlearned, rapid, predictable motor responses to a stimulus, and occur over highly specific neural pathways called reflex arcs (pp. 521–522; Marieb Fig. 13.14).

The Autonomic Nervous System

I. Introduction (pp. 533–535, Marieb Figs. 14.1–14.2)

- A. Comparison of the Somatic and Autonomic Nervous System (pp. 533–535)
 - 1. The somatic nervous system stimulates skeletal muscles, while the ANS innervates cardiac and smooth muscle and glands.
 - 2. In the somatic nervous system, the cell bodies of the neurons are in the spinal cord and their axons extend to the skeletal muscles they innervate. The ANS consists of a two-neuron chain.
 - 3. The neurotransmitter released by the somatic motor neurons is acetylcholine, which always has an excitatory effect; the neurotransmitters released by the ANS are epinephrine and acetylcholine, and both may have either an excitatory or an inhibitory effect.
 - 4. There is overlap between the somatic and autonomic nervous systems, and most body responses to changing internal and external stimuli involve both skeletal muscle activity and visceral organ responses.
- B. Divisions of the Autonomic Nervous System (p. 535)
 - 1. The parasympathetic division keeps body energy use as low as possible while directing digestion and elimination activities.
 - 2. The sympathetic division prepares the body to respond to an emergency or threatening situation (or vigorous exercise).

II. ANS Anatomy (pp. 535–542; Marieb Figs. 14.3–14.7; Marieb Tables 14.1–14.2)

- A. Parasympathetic (Craniosacral) Division (pp. 536–538; Marieb Fig. 14.4)
 - 1. The preganglionic axons extend from the CNS nearly all the way to the structures to be innervated where they synapse with ganglionic neurons in the terminal ganglia.
 - 2. The cranial outflow consists of preganglionic fibers that run in the oculomotor, facial, glossopharyngeal, and vagus cranial nerves.
 - 3. The rest of the large intestine and the pelvic organs are served by the sacral outflow, which arises from neurons located in the lateral gray matter of spinal cord segments S₂–S₄.
- B. Sympathetic (Thoracolumbar) Division (pp. 538–542; Marieb Figs. 14.5–14.6; Marieb Table 14.2)
 - 1. The sympathetic division supplies the visceral organs in the internal body cavities but also all visceral structures in the somatic part of the body.
 - 2. When synapses are made in chain ganglia, the postganglionic axons enter the ventral (or dorsal) ramus of the adjoining spinal nerves by way of communicating branches called gray rami communicantes.
 - 3. The preganglionic fibers from T₅ down synapse in collateral ganglia; thus these fibers enter and leave the sympathetic chains without synapsing.
 - 4. Some fibers of the thoracic splanchnic nerves terminate by synapsing with the hormone producing medullary cells of the adrenal cortex.

III. ANS Physiology (pp. 543–550, Marieb Tables 14.3–14.5)

- A. Neurotransmitters and Receptors (pp. 543–544; Marieb Fig. 14.8; Marieb Table 14.3)
 - 1. Cholinergic receptors, such as nicotinic and muscarinic receptors, bind acetylcholine.
 - 2. Adrenergic receptors alpha and beta bind to epinephrine.

- B. Knowing the locations of the cholinergic and adrenergic receptor subtypes allows specific drugs to be prescribed to obtain desired inhibitory or stimulatory effects on target organs (pp. 543–544; Marieb Table 14.4).