Chapter 17
Nervous System

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Introduction

- Human body has two specialized centers of control to maintain homeostasis:
  - Endocrine system (Chapter 18)
  - Nervous system (this chapter)
- Nervous system is the master control and communication center—even controls the endocrine system
- Neurology—study of functions and disorders of the nervous system

Anatomy

- Brain
- Cerebrospinal fluid
- Cranial nerves
- Meninges
- Special sense organs
- Spinal cord
- Spinal nerves

Physiology

- Sensory input—detect stimuli
- Interpretive and integrative functions—interpret input to determine response (output)
- Motor output
- Higher mental functioning and emotional responsiveness

Basic Organization of the Nervous System

- Two main divisions:
  - Central nervous system (CNS)
  - Peripheral nervous system (PNS)

Central Nervous System

- Occupies central or medial position in the body
- Interprets incoming sensory information and issues instructions in form of motor responses
- Major center for thoughts and emotional experiences
Central Nervous System

- Parts of the CNS
  - Brain (cerebrum, cerebellum, diencephalon, and brainstem)
  - Meninges
  - Cerebrospinal fluid
  - Spinal cord
- Components are surrounded by bones of the skull or spine

Peripheral Nervous System

- Composed of cranial and spinal nerves emerging from CNS
- Divisions of PNS:
  - Somatic nervous system—voluntary (governs skeletal muscles)
  - Autonomic nervous system—involuntary

Somatic Nervous System

- Sensory neurons carry information from bones, muscles, joints, skin, and sensory receptors (vision, hearing, taste, smell) to CNS
- Motor neurons carry impulses from CNS out to skeletal muscles
- Consciously controlled

Autonomic Nervous System

- Supplies impulses to smooth muscle, cardiac muscle, and glands
- Subdivided into two systems:
  - Parasympathetic—"housekeeping system" and most active under calm conditions
  - Sympathetic—"fight or flight system" and activated by physical or emotional alarm

Cells of the Nervous System

- Neuroglia (glial cells)—comprise connective tissue that supports, nourishes, protects, insulates, and organizes neurons
  - Makes up more than 50% of CNS
- Neurons (nerve cells)—conduct nerve impulses

Types of Neuroglia

Four are located in the CNS:
- Astrocytes—provide structural support in the CNS; part of blood-brain barrier
- Ependymocytes—line cranial vessels and central canal of spinal cord; assist in circulation of cerebrospinal fluid
- Microglia—protect CNS by destroying pathogens
- Oligodendrocytes—produce myelin around axons in the CNS
Types of Neuroglia

Two are located in the PNS
- Satellite cells—provide structural support of neurons in PNS
- Schwann cells—produce myelin around axons in PNS

Properties of Neurons

- Excitability—ability to respond to a stimulus and convert it to a nerve impulse
- Conductibility—ability to transmit impulses to other neurons, muscles, and glands

Parts of a Neuron

- Dendrites
  - Receive and transmit stimuli toward cell body
  - Short and highly branched
- Cell body
  - Contains nucleus and other typical cell organelles
  - Also contains Nissl bodies, which make protein for cell
  - Cell bodies comprise the gray matter of brain and spinal cord

Parts of a Neuron

- Axons
  - Carry the nerve impulse away from the neuron toward another neuron, a muscle cell, or a gland
  - Long axons are called nerve fibers
  - Have infrequent branches, called collaterals

Axon Structure

- Synaptic bulbs—small buds at the end of each axon terminal, which contain synaptic vesicles
- Telodendria—clusters of short, fine filaments at the distal end of each axon
- Synaptic vesicles—saclike structures in the synaptic bulbs that produce and store neurotransmitters

Axon Structure

- Myelin sheath—a white layer of cells that surrounds axons in the PNS and CNS
  - Electrically insulates the neuron and increases nerve impulse speed
  - In PNS, formed by Schwann cells
  - In CNS, produced by oligodendrocytes
- Nodes of Ranvier—gaps at intervals between each Schwann cell on the myelinated axon
Classification of Nerves

- Sensory (afferent) nerves—carry impulses from nerve receptors to brain or spinal cord
- Interneurons (association nerves)—process information
- Motor (efferent) neurons—carry messages from brain or spinal cord to muscle or gland

Reflex Arc

- Consists of afferent, interneuron, and efferent neurons
- Is the functional unit of the nervous system

Reflexes

- Reflex—instantaneous, automatic response to a stimulus
- Essentially a protective mechanism
- Processed in the spinal cord
- Information reaches brain after motor response (e.g., dropping a hot item) has already occurred

Types of Reflexes

- Somatic reflexes—responsible for contraction of skeletal muscle
- Visceral (autonomic) reflexes—maintain homeostasis through coughing, sneezing, blinking, heart rate adjustment, etc.

Physiopathological Reflex Arc

- Abnormal reflex arc
- Caused by increased stimuli or increased amount of afferent impulses entering spinal cord
- Result: trigger points and pain

Physiopathological Reflex Arc

- The increased stimuli can be caused by pain, emotional stress, or other dysfunction
- Massage therapy can help break physiopathological reflex arcs, restore equilibrium, and relieve pain
Neurons to Nerves

- Neuron: nerve cell
- Nerve fascicle: bundles of neurons
- Nerve: bundles of nerve fascicles comprised of neurons
- All components are held together by CT

Connective Tissue Components of Nerves

- Endoneurium—surrounds each nerve fiber
- Perineurium—surrounds groups of fibers (fascicles)
- Epineurium—surrounds groups of fascicles, forming a nerve

Resting Potentials

- No conduction of electrical signals
- Produced and maintained by active transport system called the sodium-potassium pump

Action Potentials

- Action potential, or nerve impulse, is an active neuron, or one conducting an impulse
- Electrical fluctuation that travels along the surface of a neuron’s cell membrane

Action Potential Conduction

- Na+ flows into cell due to stimulus
- This creates differential in charge along the nerve cell membrane and stimulates a nerve impulse
- Reverse polarization in initial section stimulates adjacent sections; Na+ rushes inward, stimulating the next segment
- Impulse moves in only one direction and does not decrease in speed

Action Potential Conduction

- After conduction, cell returns to resting potential via the sodium potassium pump
- Continuous conduction—nerve impulses travel along unmyelinated axons; slower
- Saltatory conduction—nerve impulses travel along myelinated axons; faster
  - Fastest fibers: 130 meters per second (300 mph)
  - Slowest fibers: .5 meters per second (1 mph)
Synapse

- Synapse—junction between two neurons or between a neuron and a muscle or gland, where transmission of nerve impulses takes place
- Two types:
  - Electrical synapses—occur between cardiac and smooth muscle cells
  - Chemical synapses—more common; comprise synaptic bulb, synaptic cleft, plasma membrane of postsynaptic neuron

Synaptic Transmission

- Nerve impulse reaches axon terminal; thousands of neurotransmitters are released into cleft
- Neurotransmitter molecules travel across synaptic cleft and make contact with plasma membrane of other neuron
- Neurotransmitters bind with receptor cites and elicit response in postsynaptic neuron

Thresholds and Summation

- Threshold—the minimum level of intensity a stimulus must reach to generate a nerve impulse
- Summation—the amount of stimuli needed to reach threshold stimulus

Neurotransmitters

- Definition: chemical messengers involved in nerve impulse transmission, which facilitate, stimulate, or inhibit
- Stored in presynaptic vesicles (as many as 10,000 molecules per vesicle)
- More than 50 compounds known to be neurotransmitters

Neurotransmitters are either excitatory or inhibitory:
- Excitatory—decrease membrane potential, increasing the impulse rate
- Inhibitory—increase membrane potential, increasing the threshold needed to cause an impulse
Types of Neurotransmitters

- Acetylcholine—vital for stimulating muscle contraction; most common neurotransmitter
- Catecholamines—cause excitation and inhibition of certain muscles, cardiac excitation, metabolic action, and endocrine action; act directly on sympathetic cells
  - Contains epinephrine, norepinephrine, and dopamine

Types of Catecholamines

- Epinephrine—acts as a hormone when secreted by adrenal medulla
- Norepinephrine—mediates responses that follow stimulation of sympathetic nerves
- Dopamine—involved with emotions, mood, attention, and learning
  - Depletion causes rigidity and uncoordinated movement

Types of Neurotransmitters

- Serotonin—important for sensory perception, mood regulation, and sleep
- Histamine—involved in emotions and regulation of body temperature and water balance
- Enkephalins and endorphins—block pain, similar to opiates

Central Nervous System

- Composed of the brain and spinal cord
- Brain housed in skull
- Spinal cord in vertebral column
- Both protected by their surrounding bones, meninges, and cerebrospinal fluid

Meninges

- Definition: connective tissue covering the brain and spinal cord
- Layers and spaces:
  - Pia mater—inmost layer
  - Arachnoid—middle layer
    - Subdural space
  - Dura mater—outermost layer
    - Epidural space

Meninges

- Diagram showing the layers and spaces of the meninges:
  - Skull
  - Subarachnoid space
  - Dura mater
  - Arachnoid
  - Pia mater
  - Cerebral cortex
Cerebrospinal Fluid

• Clear fluid, derived from blood, that supplies the tissues of the brain and spinal cord with oxygen and nutrients
• Circulates around the brain and spinal cord
• Acts as a shock absorber
• Formed in the choroid plexuses in the ventricles of the brain

Spinal Cord

• Exits skull through foramen magnum and extends to about L2
• Carries sensory impulses to the brain, and motor impulses from the brain

Spinal Cord Structure

• Lower end marked by filum terminale, which is attached to coccyx
• Ends fan out like a horse’s tail, therefore named cauda equina
• Consists of 31 segments

Brain—General Facts

• Contains about 100 billion neurons
• Uses only glucose for energy; cannot store energy
• Uses about 20% of the body’s oxygen intake
• Cells will begin to die after only 1-2 minutes without oxygen

Parts of the Brain

• Outer surface has sulci (grooves) and gyri (ridges)
  – Deep sulci are called fissures, which divide the brain into hemispheres and lobes
• Major regions:
  – Cerebrum
  – Diencephalon
  – Cerebellum
  – Brainstem
Cerebrum

- Divided into left and right hemispheres, connected by the corpus callosum
- Governs all higher functions (language, reasoning, memory)
- Largest region of brain
- Cerebral cortex—gray layer covering outer portion of cerebrum

Cerebral Lobes

- Each hemisphere divided into lobes:
  - Frontal: motor output, cognition, speech (left side)
  - Parietal: skin and muscle
  - Temporal: auditory and olfactory, language (left side)
  - Occipital: vision
  - Insula: hidden by other lobes

Specialization of Cerebral Hemispheres

- Left hemisphere:
  - motor control of right half of body
  - language (receptive and expressive)
  - skilled and general hand movements
- Right hemisphere:
  - Perception of nonspeech sounds (melodies, coughing, crying, laughing)
  - Perception of spatial relationships
- Hemispheres communicate with each other via the corpus callosum

Brain Waves

- Definition: rhythmic electric impulses produced in the cerebral cortex and measured by EEG
- Four different patterns, associated with various states of consciousness:
  - Beta (13-30 Hz): wakefulness, mental activity
  - Alpha (8-12 Hz): relaxed, nonattentive state
  - Theta (4-8 Hz): drowsiness, dreamlike awareness, collective subconscious
  - Delta (.5-4 Hz): deep sleep
Diencephalon
- Located in the center of the brain
- Houses the thalamus and hypothalamus
- Thalamus—interprets all sensory impulses except olfaction
  - 80% of the diencephalon is the thalamus
- Hypothalamus—regulates autonomic nervous system and endocrine system

Cerebellum
- Located posterior and inferior to cerebrum
- Contains two hemispheres
- Cerebellar cortex—outer layer of gray matter
- Involved with muscle tone, complex movements, posture, and balance

Brainstem
- Midbrain:
  - Conducts nerve impulses from the cerebrum to the pons and sensory impulses from the spinal cord to the thalamus
  - Controls movements of the eyes, head, and neck
- Pons:
  - Relays nerve impulses from one side of the cerebellum to another
  - Helps control breathing

Pituitary gland—connected to hypothalamus by the infundibulum
Pineal gland—secretes melatonin
Brainstem
• Medulla Oblongata:
  – Most inferior portion
  – Conducts sensory and motor impulses between other parts of the brain and the spinal cord
  – Contains fibers linking left cerebral hemisphere to right side of body and vice versa
  – Often considered the most vital part of brain—contains respiratory, cardiovascular, and vasomotor centers

Blood-Brain Barrier
• Selective semipermeable wall of blood capillaries
• Prevents or slows passage of some chemicals and pathogens (e.g., viruses) from blood to the CNS
• Purpose is to protect brain from potentially harmful substances, even components of blood itself

Peripheral Nervous System
• Contains all the nerves outside of the CNS
• Subdivided into the somatic nervous system and the autonomic nervous system
• Spinal nerves: peripheral nerves arising from spinal cord (31 pairs)
• Cranial nerves: peripheral nerves arising from brain (12 pairs)

Spinal Nerves
• Each pair joins the spinal column at two points, on left and right
• Each nerve has two roots:
  – Anterior (ventral) root contains motor neurons
  – Posterior (dorsal) root contains sensory neurons

Spinal Nerves
• Posterior root contains cluster called posterior or dorsal (sensory) root ganglion
• All spinal nerves have sensory and motor components
• Ganglion—cluster of nerve cell bodies located in the PNS

Nerve Plexuses
• Plexus: network of intersecting nerves in PNS
  – Cervical plexus (C1-C5) supplies head and neck
  – Brachial plexus (C5-T1) supplies arm and hand
  – Lumbar plexus (L1-L4) supplies abdomen, low back, and genitals
  – Sacral plexus (L4-S4) supplies posterior hip, legs, and feet
Dermatomes

- An area of skin served by a specific sensory nerve root (C2-S5) or by one branch of the fifth cranial (trigeminal) nerve
- Roughly the same from person to person

Myotomes

- A group of skeletal muscles innervated by a single spinal segment
- Some overlap exists among myotomes

Nerves of Importance to Massage Therapists

- Some cranial nerves, spinal nerves, and plexuses can be compressed during massage
- Compression can cause numbness, tingling, burning, or pain

Important Nerves

- Axillary nerve—deltoids and teres minor (shoulder)
- Brachial plexus—arm and hand
- Common peroneal nerve—ankle and foot
- Facial nerve

Important Nerves

- Femoral nerve—hip and knee
- Median nerve (great flexor)—forearm, wrist, and hand
- Lumbar plexus—abdomen, low back, genitalia
Important Nerves

• Musculocutaneous nerve—elbow and shoulder
• Obturator nerve—hip
• Radial nerve (great extensor)—elbow, wrist, and hand
• Sciatic nerve—hip

Important Nerves

• Tibial nerve—ankle, foot, knee, hip
• Ulnar nerve (accessory flexor)—forearm, wrist, and hand
• Vagus nerve—heart, lungs, kidney, gastrointestinal tract

Cranial Nerves

• 12 pairs
• Named by Roman numerals or the area the nerves supply
• Emerge from inferior surface of brain

Cranial Nerves

• (I) Olfactory—smell
• (II) Optic—vision
• (III) Oculomotor—moves eyeball and eyelid; constricts pupil
• (IV) Trochlear—moves eyeball
• (V) Trigeminal (great sensory nerve of face and head)—three branches for chewing, pain, and temperature
• (VI) Abducens—moves eyeball
• (VII) Facial—makes facial expression; produces saliva and tears
Cranial Nerves

- (VIII) Vestibulocochlear (auditory or acoustic)—equilibrium and hearing
- (IX) Glossopharyngeal—produces saliva; employs taste and swallowing
- (X) Vagus—receives signals from external ear and thoracic and abdominal organs; aids digestion; helps regulate heart activity

Cranial Nerves

- (XI) Accessory (spinal accessory)—controls tongue for speech and swallowing; innervates trapezius and sternocleidomastoid
- (XII) Hypoglossal—moves tongue for speech and swallowing

Autonomic Nervous System

- Innervates cardiac muscle, smooth muscle, and glands
- Subdivided into sympathetic and parasympathetic nervous systems

Parasympathetic Nervous System

- “Rest-and-digest” system: supports body functions that conserve and restore body energy
- Can be considered the body’s “housekeeping system”
- Regulates salivation, urination, digestive processes, defecation, and nutrient storage

Parasympathetic Nervous System

- Fibers occupy spaces at levels S2 to S4 and cranial nerves III, VII, IX, and X
- Often called craniosacral outflow
Sympathetic Nervous System

• “Fight-or-flight” system: overrides the parasympathetic division during exertion or stress
• Triggers the adrenal gland to secrete epinephrine, which sustains action of the sympathetic nervous system throughout the endocrine system

Sympathetic Nervous System

• Body responses include pupil dilation, increased heart rate, airway dilation, energy mobilization, etc.
• Processes not needed to meet the stress (e.g., digestive tract movements) are suppressed
• Often called thoracolumbar outflow

Sense Organs

• All sense receptors arise from ectoderm (same layer as gives rise to brain and spinal cord)
• Touch, a general sense, involves the entire body
• Special senses (taste, olfaction, vision, hearing) reside in the head

Touch

• Sense of touch is an amalgamation of specialized receptors found in the skin
• Skin can sense heat, cold, pressure, pain, and movement
• Most primitive of all sensations and earliest to develop in embryos

Taste

• Mediated by taste buds (gustatory organs) located on tongue projections called papillae
• Type of receptor is chemoreceptor

Taste

• Taste buds contain taste hairs linked to a series of receptors
• Taste is strongly influenced by sense of smell
Olfaction (smell)

- Uses chemoreceptors to detect odors
- Receptors are found in nasal cavity and nasal mucosa
- Has strongest link to memories

Vision

- Uses photoreceptors (rods and cones) located in the eye
- Light enters the pupil and strikes the retina

Vision

- Each eye has a blind spot where the optic nerve exits the retina; this is compensated for by the presence of two eyes

Hearing

- Responds to air vibrations detected by mechanoreceptors
- Sound waves hit the tympanic membrane (eardrum), causing it to vibrate
- Vibration is passed along to the three inner-ear bones (ossicles)

Hearing

- Sound waves cause membrane of oval window to vibrate
- Vibration is passed to fluid of cochlea

Characteristics of Sound

- Pitch—quality of a tone or sound, dependent on vibration frequency
- Volume—loudness of sound; can change without altering pitch
Types of Sensory Receptors

• Classified by location:
  – Exteroceptors—in the skin, react to external stimuli
  – Proprioceptors—in the skin, ears, muscles, tendons, joints, and fascia; respond to movement and position
  – Interoceptors—in the viscera, respond to internal stimuli

Chemoreceptors

• Located in nose, tongue, some arterial walls, brain
• Detect smells, tastes, and blood chemistry changes
• Chemoreceptors in aorta and other blood vessels detect low oxygen—increase respiration rate

Types of Mechanoceptors

• Touch and pressure receptors: Meissner, Ruffini's, and Pacinian corpuscles and Krause end bulbs, Merkel disks, and hair root plexus
• Stretch receptors:
  – Muscle spindle: stretch-sensitive receptors; monitors changes in muscle length and causes reflex contraction
  – Golgi tendon organ: inhibits motor neurons & thus contraction if muscle tension too high
Types of Mechanoreceptors

- Baroreceptors—located in walls of carotid arteries and aortic arch
  - Detect blood pressure
  - Send signals to cardiac center and vasomotor center
  - CNS signals autonomic nervous system to adjust heart rate and vessel diameter

Photoreceptors

- Rods and cones are photoreceptors located in the retina
  - Rods detect dim light, black, white, and shades of gray
  - Cones detect color; three types are normally present, each sensitive to a different wavelength of light

Nociceptors

- Detect pain
- Present in most tissues except the brain
- Rarely adapt to prolonged stimulus (so person does not ignore a potentially harmful stimulus)

Thermoreceptors

- Located immediately under the skin
- Two types: one for cold and one for heat
- Nociceptors (pain receptors) are triggered by extreme temperatures

Pathological Conditions

- Alzheimer’s disease—characterized by confusion, memory failure, disorientation, restlessness, delusions, and speech and movement impairment
- Anxiety disorders—episodes of severe intense anxiety and panic
- Bell’s palsy—unilateral facial paralysis of sudden onset resulting from inflammation of cranial nerve VII (facial nerve)

Pathological Conditions

- Bipolar disorder—mood disorder in which both depressive and manic episodes occur
- Carpal tunnel syndrome—repetitive stress injury caused by compression of median nerve by transverse carpal ligament
- Cataract—partial or complete lack of transparency in the lens or lens capsule of the eye that can impair vision or cause blindness
Pathological Conditions

- Cerebral palsy—motor disorders resulting in loss of muscle control
- Dementia—cognitive disorder resulting in personality disintegration, disorientation, and general loss of cognitive abilities
- Depression—mood disorder resulting in deep sadness, despair, pessimism, low self-esteem, withdrawal from personal contact, decreased energy, sleep and eating disturbances

Pathological Conditions

- Encephalitis—inflammation of the brain caused by disease, hemorrhage, poisoning, or other conditions
- Erb’s palsy—caused by injury to upper brachial plexus, resulting in paralysis of the arm
- Glaucoma—elevated pressure within one or both eyes caused by an obstruction of the outflow of aqueous humor

Pathological Conditions

- Guillain-Barré syndrome—rapidly progressive peripheral nerve paralysis
- Lou Gehrig’s disease—degeneration of motor neurons resulting in weakness and muscle atrophy of hands, forearms, legs
- Macular degeneration—progressive deterioration of the retinal maculae
- Meningitis—infection or inflammation of the meninges

Pathological Conditions

- Multiple sclerosis (MS)—autoimmune disorder that causes destruction of the myelin sheaths
- Myasthenia gravis—autoimmune disorder resulting in loss or impairment of ACh receptors
- Nerve compression—nerve impingement
- Nerve entrapment—dysfunction caused by pressure from adjacent soft tissues

Pathological Conditions

- Neuropathy—degeneration of the PNS
- Obsessive-compulsive disorder—anxiety disorder characterized by emotionally constricted mannerisms that are overly conventional and rigid
- Paralysis—loss of muscle function and/or sensation due to injury, illness, or poisoning

Pathological Conditions

- Parkinson’s disease—progressive neurological disease caused by destruction of dopamine-producing neurons and depletion of dopamine
- Pinkeye—inflammation of the conjunctiva of the eye caused by infection, allergy, or debris
- Poliomyelitis (polio)—infectious disease caused by one of three viruses
Pathological Conditions

• Reflex sympathetic dystrophy (RSD)—complex disorder affecting limbs; caused by trauma
• Sciatica—caused by inflammation of the sciatic nerve
• Seizure disorders (epilepsy)—presence of abnormal and irregular discharges of cerebral electrical activity

Pathological Conditions

• Spina bifida—congenital defect, involves lack of bone development in the lamina (posterior vertebral arch)
• Stroke—a blockage of cerebral blood vessels, resulting in ischemia of brain tissue
• Substance abuse—use of a mood- or behavior-altering substance that results in distress or impairment

Pathological Conditions

• Thoracic outlet syndrome (TOS)—caused by compression of the brachial nerve, often between clavicle and first rib
• Trigeminal neuralgia—excruciating episodic pain in the areas supplied by the trigeminal nerve, or cranial nerve V

Summary

• Neurons are the functional unit of the nervous system
• Nerve impulses (action potentials) are result of ions changing place, creating different electrical charges along cell membrane
• Nervous system divisions:
  – CNS—brain and spinal cord
  – PNS—sensory and motor neurons

Summary

• PNS is further subdivided into somatic and autonomic nervous systems
  – Somatic—voluntary
  – Autonomic—involuntary
• Autonomic system is divided into the parasympathetic and sympathetic systems
  – Parasympathetic—“rest and digest”
  – Sympathetic—“fight or flight”