Overview of the Nervous System

- Central nervous system (CNS)
  - Brain and spinal cord
- Peripheral nervous system (PNS)
  - Cranial nerves
  - Spinal nerves
  - Pathways
    - Afferent (ascending)
    - Efferent (descending)

Cells of the Nervous System

- Neuron (conducts nerve impulses)
  - Variable size and structure
- Three components
  - Cell body (soma)
    - Nuclei = cell bodies in the CNS
    - Ganglia = cell bodies in the PNS are ganglia
  - Dendrites
    - Receive impulses
  - Axons
    - Carry impulses away from the cell body

Neuron

- Axons
  - Myelin
    - Insulating layer of lipid material
    - Formed by the Schwann cell
  - Endoneurium
    - Delicate layer of CT around each axon
  - Neurilemma
    - Thin membrane between the myelin sheath and the endoneurium

Overview of the Nervous System

- Peripheral nervous system (PNS)
  - Somatic nervous system
    - Motor (efferent) and sensory (afferent) pathways regulating voluntary motor control of skeletal muscle
  - Autonomic nervous system (ANS)
    - Motor and sensory pathways regulating the body’s internal environment through involuntary control of organ systems
      - Sympathetic (“Fight or flight”)
      - Parasympathetic (“Rest and repose”)

Structure and Function of the Nervous System

Chapter 12

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**Neuron**

- Axons
  - Nodes of Ranvier
    - Regular interruptions of the myelin sheath
  - Saltatory conduction
    - The flow of ions between segments of myelin rather than along the entire length of the axon

**Structural Classification of Neurons**

- Based on the number of processes extending from the cell body
  - Unipolar
  - Bipolar
  - Multipolar

**Functional Classification of Neurons**

- Sensory (afferent)
  - Transmit impulses from sensory receptors to the CNS
- Associational (interneurons)
  - Transmit impulses from neuron to neuron
- Motor (efferent)
  - Transmit impulses from the CNS to an effector

**Neuroglia**

- “Nerve glue”
- Support the neurons of the CNS
  - Astrocytes
  - Oligodendroglia (oligodendrocytes)
  - Microglia
  - Ependemal
**Nerve Impulse**

- Neurons generate action potentials by selectively changing the **electrical** portion of their plasma membranes and influencing other nearby neurons by release of neurotransmitters (**chemicals**).

**Synapses**

- Region between adjacent neurons (pre- and postsynaptic neurons) is called a synapse.
- Impulses are transmitted across the synapse by chemical and electrical conduction.
- Neurotransmitters
  - More than 30 substances
    - (ACh, serotonin, NE, dopamine)
  - Excitatory or Inhibitory.

**Central Nervous System**

**BRAIN:**
- Forebrain
  - Cerebral hemispheres
- Midbrain
  - Corpora quadrigemina, substantia nigra, and cerebral peduncles
- Hindbrain
  - Cerebellum, pons, and medulla

**Diencephalon**
- Thalamus
- Hypothalamus

**Midbrain**
- Corpora quadrigemina
  - Superior and inferior colliculi
- Tegmentum
  - Red nucleus and substantia nigra (⇒ dopamine ⇒ NE)
  - Cerebral peduncles
Central Nervous System

- Hindbrain
  - Cerebellum
  - Pons
  - Medulla oblongata

Spinal Cord

- Located in **vertebral canal**, protected by the **vertebral column**
  - Connects the brain and the body
  - Conducts somatic and autonomic reflexes
  - Modulates sensory and motor function

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Reflex Arc

- Receptor
- Afferent (sensory) neuron
- Efferent neuron
- Effector

Neuromuscular Junction

- Motor neuron fiber
- Myelin sheath
- Schwann cell
- Synaptic vesicles
- Sarcolemma
- Acetylcholine receptor sites
- Synaptic cleft
- Motor end-plate
Protective Structures

• **Cranium**
  – Eight bones
    • Frontal, Occipital, Temporal (2), Parietal (2), Sphenoid, Ethmoid
    • Galea aponeurotica

• **Meninges**
  – Protective membranes surrounding brain & SC s
    • Dura mater
    • Arachnoid
    • Pia mater

Protective Structures

• **Cerebrospinal fluid (CSF)**
  – Clear, colorless fluid similar to blood plasma and interstitial fluid
  – 125 to 150 mL
  – Produced by choroid plexuses in the lateral, third, and fourth ventricles
  – Reabsorbed through arachnoid villi

Protective Structures

• **Vertebral column**
  – 33 vertebrae
    • 7 cervical, 12 thoracic, 5 lumbar, 5 fused sacral, 4 fused coccygeal
  – Intervertebral disks
    • Nucleus pulposus

Vertebral Column

Blood Supply to the Brain

• 800 to 1000 mL per minute
• CO₂ is the primary regulator for CNS blood flow
• Internal carotid and vertebral arteries
• Arterial circle (circle of Willis)
Peripheral Nervous System

- **31 pairs of spinal nerves**
  - Named for vertebral level from which they exit
  - Mixed nerves
  - Arise from gray matter of the spinal cord

- **12 pairs of cranial nerves**
  - Sensory, motor, and mixed

Autonomic Nervous System

- Located in both the CNS and PNS
- Maintains a homeostasis in visceral (internal) organs
- Neurons
  - Preganglionic (myelinated)
  - Postganglionic (unmyelinated)
**Autonomic Nervous System**

- Two divisions
  - Sympathetic
    - "Fight or flight" response
    - Thoracolumbar
    - Sympathetic (paravertebral) ganglia
  - Parasympathetic
    - "Rest or repose" response
    - Craniosacral
    - Preganglionic neurons travel to ganglia close to organs they innervate

**Sympathetic Nervous System**

**Parasympathetic Nervous System**

**Neurotransmitters and Neuroreceptors of the ANS**

- SNS preganglionic fibers
  - ACh (cholinergic)
- SNS postganglionic fibers
  - NE (adrenergic)
- PSN preganglionic and postganglionic fibers
  - ACh

**Aging and the Nervous System**

- Decrease in the number of neurons
  - Decreased brain weight and size
- Senile plaques
- Neurofibrillary tangles
- Slowing of neurologic responses
Concept Check:

1. One function of the somatic NS that is not performed by the ANS is conduction of impulses:
   - A. To involuntary muscles and glands
   - B. To the CNS
   - C. To skeletal muscles
   - D. Between the brain and SC

2. Neurons are specialized for the conduction of impulses, while neuroglia:
   - A. Support nerve tissue
   - B. Serve as motor end plates
   - C. Synthesize ACh and AChE
   - D. All of the above

3. Which of the following best describes the SC?
   - A. Descends inferior to the lumbar vertebrae
   - B. Conducts motor impulses from the brain
   - C. Descends to L4
   - D. Conducts sensory impulses to the brain

4. Which is not a protective covering of the CNS?
   - A. Cauda equina
   - B. Dura mater
   - C. Arachnoid
   - D. Cranial bone

5. The SNS:
   - A. Mobilizes E in times of need
   - B. Is innervated by cell bodies from T1 → L2
   - C. Is innervated by cell bodies located in the cranial nerve nuclei
   - D. Both A and B are correct

6. The PSN:
   - A. Conserves and stores E
   - B. Has relatively short postganglionic neurons
   - C. Both A and B are correct
   - D. Has paravertebral ganglia

Pain, Temperature, Sleep, and Sensory Function

Chapter 13

Pain

• “Pain is whatever the experiencing person says it is, existing whenever he says it does” —McCaffrey

Neuroanatomy of Pain

• Nociception
  - Perception of pain
• Nociceptors
  - Free nerve endings in skin, muscle, joints, arteries, and the viscera that respond to chemical, mechanical, and thermal stimuli
**Pathways of Nociception**

- Spinothalamic tracts

**Neuromodulation of Pain**

- Neuromodulators
  - Located in pathways of NS
  - Triggered by tissue injury and/or inflammation
  - Excitatory neuromodulation
    - Substance P, glutamate, somatostatin
  - Inhibitory neuromodulation
    - GABA, glycine, serotonin, NE, endorphins

**Neuromodulation of Pain**

- Endorphins (endogenous morphines)
  - Neuropeptides – inhibit pain transmission in CNS
  - Bind opioid receptors
- Beta-endorphins (rel. from hypothalamus & pit. gland)
- Enkephalin (weaker than other endorphins)
- Dynorphins (can stimulate pain)
- Endomorphins (cause VD due to NO released from endothelial cells)

**Endorphin Response**

**Acute Pain**

- Manifestations
  - Fear and anxiety
    - Tachycardia, hypertension, fever, diaphoresis, dilated pupils, outward pain behaviors, elevated BG, decreased gastric acid secretion and intestinal motility, and a general decrease in blood flow
- Referred pain
  - Pain present in an area removed or distant from point of origin
  - Area of referred pain is supplied by same spinal segment as the actual site
  - Myocardial infarction pain
Chronic Pain

- May be sudden or develop insidiously
- Usually defined as lasting at least 3 to 6 months
- Produces significant behavior and psychologic changes
- Types:
  - Low back pain
  - Myofascial pain syndromes
  - Chronic postoperative pain
  - Cancer pain

Neuropathic Pain

- Result of trauma or disease of nerves
- Peripheral
  - Painful diabetic neuropathy
- Central
  - Phantom limb

Temperature Regulation

- Peripheral & central thermoreceptors
- Hypothalamic control (range ~37°C ± 0.7°C)
- **Heat production**
  - Metabolism
  - Skeletal muscle contraction
  - Chemical thermogenesis
- **Heat conservation**
  - Vasoconstriction
  - Voluntary mechanisms

Heat Loss

- Radiation, Conduction, Convection
- Vasodilation
- Decreased muscle tone
- Evaporation
- Increased respirations
- Voluntary measures
- Adaptation to warmer climates

Temperature Regulation

- Aging
  - Slow blood circulation, vasoconstrictive response, and metabolic rate
  - Decreased sweating and perception of heat and cold

Fever

- Resetting of the hypothalamic thermostat
- Activate heat production and conservation measures to a new “set point”
- Pyrogens (exogenous or endogenous) toxins from pathogens → PG (which reset thermostat)
Bio217

Unit IV

Fever

- Benefits of Fever
  - Kills many microorganisms
  - Decreases serum levels of Fe, Zn, and Cu
  - Promotes lysosomal breakdown and autodestruction of cells
  - Increases lymphocytic transformation and phagocyte motility
  - Augments antiviral interferon production

Hyperthermia

- Not mediated by pyrogens (no resetting of thermostat)
- 41°C (105.8°F): nerve damage produces convulsions
- 43°C (109.4°F): death results
- Forms
  - Heat cramps (abdom. pain, incr. sweat, loss Na+)
  - Heat exhaustion (collapse, profuse sweat, high core temp.)
  - Heatstroke (death, brain cannot tolerate temperatures >40.5°C (104.9°F))

Hypothermia

- Body temperature less than 35°C
- Produces:
  - VC, alterations in the microcirculation, coagulation, and ischemic tissue damage
  - Ice crystals, which form inside the cells, causing them to rupture and die

Hypothermia

- Accidental hypothermia
  - Commonly the result of sudden immersion in cold water or prolonged exposure to cold
- Therapeutic hypothermia
  - Used to slow metabolism and preserve ischemic tissue during surgery or limb reimplantation
  - May lead to ventricular fibrillation and cardiac arrest

Sleep

- Infants: 16-17 hours/day; about half in REM
- Elderly: decrease in sleep time, longer to fall asleep; increase in sleep apnea

REM = rapid eye movement sleep; 90 minute cycles after non-REM sleep
Sleep Disorders

• Insomnia
  – not able to fall asleep or stay asleep
  – idiopathic, abuse of drugs or alcohol, chronic pain, depression, or certain drugs, age, obesity

• Obstructive sleep apnea
  – Upper airway blockage
  – \( \rightarrow \) snoring
  – Apneic episodes > 10 sec.

Vision

• Blepharitis
  – Inflammation of the eyelids

• Hordeolum (stye)
  – Infection of the sebaceous glands of the eyelids

• Chalazion
  – Infection of the meibomian (oil-secreting) gland

• Keratitis
  – Infection of the cornea

External Eye Disorder

• Conjunctivitis
  – Inflammation of the conjunctiva

  • Acute bacterial conjunctivitis (pinkeye)
    • Highly contagious
    • Mucopurulent drainage from one or both eyes
    – Viral, Allergic, or Trachoma (chlamydial) conjunctivitis

Vision Changes and Aging

• Cornea
• Anterior chamber
• Lens
• Ciliary muscles
• Retina

Visual Dysfunctions

• Alterations in visual acuity
  – Cataracts – cloudy lens due to degeneration (age)
  – Glaucoma – increase in intraocular pressure
  – Age-related macular degeneration (AMD)
    – major cause of blindness in elderly; increased risk due to HT, smoking, diabetes mellitus
Aging and Hearing

- Cochlear hair cell degeneration
- Loss of auditory neurons in spiral ganglia of organ of Corti
- Degeneration of basilar conductive membrane of the cochlea
- Decreased vascularity of cochlea
- Loss of cortical auditory neurons

Ear Infections

- Otitis externa
  - Infection of the outer ear
  - Commonly caused by prolonged moisture exposure (swimmer’s ear)

- Otitis media
  - Acute otitis media
  - Otitis media with effusion

Auditory Dysfunction

- Mixed hearing loss – combination of conductive and sensorineural loss

- Functional hearing loss – no known cause

- Ménière disease – middle ear affected, hearing and balance are impaired

Concept Check

- 1. Endorphins:
  - A. Increase pain sensations
  - B. Decrease pain sensations
  - C. May increase or decrease pain
  - D. Have no effect on pain

- 2. IL-1:
  - A. Raises hypothalamic set point
  - B. Is an endogenous pyrogen
  - C. Is stimulated by exogenous pyrogens
  - D. All of the above
3. In heatstroke—
   – A. Blood viscosity increases
   – B. Core temp. increases as regulatory center fails
   – C. Stimulates VC
   – D. Ice crystals form in cells

Matching:

4. Meniere
disease A. due to airway obstruction during breathing
5. AMD B. Vestibular & hearing disruption
6. AOM C. Retinal detachment & loss of photoreceptors
7. Sleep apnea D. Effusion behind tympanic membrane

Alterations in Cognitive Networks

• Consciousness
  – State of awareness of oneself and env.
  – Arousal
    • State of awareness
    • Content of thought

Levels of Consciousness

• Consciousness – alert and aware of person, place, time
• Confusion – not able to think
• Lethargy – limited speech, may/maynot be oriented to PPT
• Obtundation – stimulation needed for arousal
• Stupor – unresponsive except for vigorous stimuli
• Coma – no vocalization or arousal

Alterations in Arousal

• Coma is produced by either:
  – Bilateral hemisphere damage or suppression
  – Brain stem lesions or metabolic derangement that damages or suppresses the RAS
    • RAS (reticular activating system = maintains wakefulness; consists of nuclei in brainstem and extends to cerebral cortex)
      – No verbal responses to stimuli
      – No reaction to deep pain
Alterations in Arousal
- Clinical manifestations of Coma
  - Level of consciousness changes
  - Pattern of breathing
    - Posthyperventilation apnea (PHVA)
    - Cheyne-Stokes respirations (CSR)
  - Vomiting
  - Pupillary changes
  - Oculomotor responses
  - Motor responses

Seizures
- Sudden, transient alteration of brain function caused by an abrupt explosive, disorderly discharge of cerebral neurons
- Motor, sensory, autonomic, or psychic signs
- Convulsion
  - Tonic-clonic (jerky, contract-relax) movements associated with some seizures

Dementia
- Progressive failure of cerebral functions that is not caused by an impaired level of consciousness
  - Classifications
    - Cortical
    - Subcortical

Alzheimer Disease (AD)
- Familial, early and late onset
- Nonhereditary (sporadic, late onset)
- Theories
  - Mutation for encoding amyloid precursor protein
  - Alteration in apolipoprotein E
  - Loss of neurotransmitter ACh

Alzheimer Disease (AD)
- Neurofibrillary tangles
- Senile plaques
- Clinical manifestations
  - Forgetfulness, emotional upset, disorientation, confusion, lack of concentration, decline in abstraction, problem solving, and judgment
- Diagnosis is made by ruling out other causes of dementia

Alterations in Movement
- Huntington disease
  - Also known as “chorea”
  - Autosomal dominant hereditary-degenerative disorder
  - Severe degeneration of the basal ganglia (caudate nucleus) and frontal cerebral atrophy
  - Depletion of gamma-aminobutyric acid (GABA)
Alterations in Movement

- Hypokinesia
  - Decreased movement
- Akinesia
- Bradykinesia
- Loss of associated movement

Parkinson Disease

- Severe degeneration of the basal ganglia (corpus striatum) involves dopamine secreting cells
  - Parkinsonian tremor
  - Parkinsonian rigidity
  - Parkinsonian bradykinesia
  - Postural disturbances

Concept Check

Matching:
1. Confusion
2. Lethargy
3. Obtundation
4. Stupor
5. Coma

- a. No speech or arousal
- b. Only responses to strong stimuli
- c. Stimulation necessary for arousal
- d. Speech limited, may or may not be oriented
- e. Not able to think straight

Alterations of Neurologic Function

- 6. AD a. Autosomal dominant, GABA decreased
- 7. HD b. Decreased dopamine, resting tremors
- 8. PD c. Neurofibrillary tangles, amyloid proteins
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Unit IV

Brain Trauma

• Major head trauma
  – Traumatic insult to the brain → physical, intellectual, emotional, social, and vocational changes
  – Transportation accidents
  – Falls
  – Sports-related event
  – Violence

Brain Trauma

• Closed (blunt, nonmissile) trauma
  – Head strikes hard surface or a rapidly moving object strikes the head
  – The dura intact, brain tissue not exposed to the env.
  – Causes focal (local) or diffuse (general) brain injuries

• Open (penetrating, missile) trauma
  – Injury breaks dura, exposes cranial contents to env.
  – Causes primarily focal injuries

Focal Brain Injury

• Observable brain lesion
• Force of impact produces contusions (bruise)
• Contusions can cause:
  – Extradural (epidural) hemorrhages or hematomas
  – Subdural hematomas
  – Intracerebral hematomas

Hematomas

– collection of blood in closed space

Subdural Hematomas
Mild Concussion
- Temporary axonal disturbance → attention and memory deficits but no loss of consciousness
- I: confusion, disorientation, and momentary amnesia
- II: momentary confusion and retrograde amnesia
- III: confusion with retrograde (events preceding trauma) and anterograde amnesia (unable to form recent memories)

Classic Cerebral Concussion
- Grade IV
  - Disconnection of cerebral systems from the brain stem and reticular activating system
  - Physiologic and neurologic dysfunction without substantial anatomic disruption
  - Loss of consciousness (<6 hours)
  - Anterograde and retrograde amnesia
  - Postconcussive syndrome (headaches, anxiety, insomnia, depression, unable to concentrate)

Spinal Cord Trauma
- Most commonly occurs due to vertebral injuries
  - Simple fracture, compressed fracture, and comminuted fracture and dislocation
- Traumatic injury of vertebral and neural tissues as a result of compressing, pulling, or shearing forces
Spinal Cord Trauma

• Spinal shock
  – Normal activity of the spinal cord ceases at and below the level of injury. Sites lack continuous nervous discharges from the brain.
  – Complete loss of reflex function below level of lesion

Degenerative Disorders of the Spine

• Degenerative disk disease (DDD)
  – Spondylolysis – structural defect of lamina or vertebral arch (lumbar)
  – Spondylolisthesis - vertebra slides forward
  – Spinal stenosis – narrowing of spinal canal, puts pressure on nerves (sciatica)
• Low back pain
• Herniated intervertebral disk – protusion of nucleus pulposus

Cerebrovascular Disorders

• Cerebrovascular accident (CVA) – stroke
  – Impairment of cerebral circulation
  – Leading cause of disability
  – 3rd leading cause of death in United States
  – Classified
    • Global hypoperfusion (as in shock)
    • Ischemia (thrombotic, embolic)
    • Hemorrhagic

• Cerebrovascular accidents (CVAs)
  – Thrombotic stroke
    • Arterial occlusions caused by thrombi formed in arteries supplying the brain
    • Due to obesity, smoking, OC, surgery
    • Transient ischemic attacks (TIAs)
  – Embolic stroke
    • Fragments that break from a thrombus formed outside the brain
    • Can also be from fat, tumor, bacteria, air
    • Middle cerebral artery is site of emboli

• Hemorrhagic stroke (intracranial hemorrhage)
  – Due to HT, aneurysms
  – Causes sudden rupture of cerebral artery
  – ➔ blood accumulating deep in brain
    ➔ further neural tissue compromise
TIA (transient ischemic attack)
- Recurring episode of neurologic deficit
- Lasts seconds to hours (clears in 12-24 hours)
- Microemboli → temporary interruption of blood flow
- Also small spasms of brain arterioles
- Double vision, blindness (unilateral), uncoordinated gait, fall due to weakness in legs, dizzy, slurred speech
- Temporary – clears in 12-24 hours
- Impending stroke sign – warning of stroke
- Aspirin or Anticoagulant is given to minimize blood clots

Intracranial Aneurysm

Infection and Inflammation of the CNS
- Meningitis
  - Bacterial meningitis
  - Aseptic (viral, nonpurulent, lymphocytic) meningitis
  - Fungal meningitis
  - Tubercular (TB) meningitis

Demyelinating Disorders
- Multiple sclerosis (MS)
  - MS is a progressive, inflammatory, demyelinating disorder of the CNS
  - Involves optic, oculomotor & spinal tracts
  - Ups and downs of MS – exacerbations & remissions
  - Occurs in women mostly (18-40yrs.)
  - Causes: viral, autoimmune, genetic, stress
  - Symptoms: optic neuritis & sensory impairment (paresthesia)
  - Prognosis varies

Understanding Demyelination
- Myelin (white matter) = lipoprotein that speeds nerve impulse conduction
- Injury to myelin by hypoxemia, chemicals, or autoimmune responses
- Leads to inflammation, breakdown of layers and formation of plaque (scar tissue)
- Damaged myelin sheath not able to conduct AP → neurologic dysfunction
Neuromuscular Junction Disorders

- **Myasthenia gravis** ("grave muscular weakness")
  - Chronic autoimmune disease
  - Antibodies produced against acetylcholine receptors
  - Weakness and fatigue of muscles head and neck → diplopia, difficulty chewing, talking, swallowing
  - Causes: unknown, autoimmune, disorders of thymus
  - Symptoms: progressive muscle weakness, respiratory distress (if diaphragm is involved)
  - Treatment: Anticholinesterase drugs, Corticosteroids

NMJ

- During normal NMJ transmission- motor neuron AP travels to axon terminal → release of ACh (neurotransmitter) → diffuses across cleft and attach to receptor sites on motor end plate → depolarization of muscle fiber.
- In MG – antibodies attach to ACh receptors and block the ACh from attaching → blocked neuromuscular transmission

**Concept Check**

1. If an individual struck the car windshield in a car accident, the coup/contrecoup injury would be in the:
   - A. Frontal/parietal region
   - B. Frontal/occipital region
   - C. Parietal/occipital region
   - D. Occipital/frontal region

2. Injury of the cervical SC may be life threatening due to:
   - A. Increased intracranial pressure
   - B. Spinal shock
   - C. Loss of bladder and rectal contrao
   - D. Impairment of the diaphragm

3. TIAs are:
   - A. Neurological deficits that slowly resolve
   - B. Neurological deficits that occur every hour
   - C. Focal neurological deficits that dev. suddenly, last for a few minutes, and clear in 24 hours
   - D. Events that never indicate an impending stroke

**Matching**

4. **MG**
   - a. Autoimmune disorder, antibodies attack ACh receptors at NMJ

5. **MS**
   - b. Protrusion of nucleus pulposus

6. Herniated disc
   - c. Demyelination of nerves