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 CNS
    - Ganglia = cell bodies in PNS are ganglia
  - Dendrites
    - Receive impulses
  - Axons
    - Carry impulses away from 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 myelin sheath and endoneurium
Neuron

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

Structural Classification of Neurons

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

Functional Classification of Neurons

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

Forebrain:

- Functional areas
  - Cerebral cortex
    - Gyri, sulci, and fissures
    - Gray matter and white matter
    - Cerebral nuclei (basal ganglia)

Central Nervous System

- 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 **vertebral column**
  - Connects the brain and the body
  - Conducts somatic and autonomic reflexes
  - Modulates sensory and motor function

Spinal Cord

Reflex Arc

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

Neuromuscular Junction
Protective Structures

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

- **Meninges**
  - Protective membranes surrounding brain & SC
    - 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 lateral, third, and fourth ventricles
  - Reabsorbed through arachnoid villi

Vertebral Column

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

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)
Blood Supply to the Brain

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

**Parasympathetic Nervous System**

- Neurotransmitters and Neuroreceptors of the ANS
  - SNS preganglionic fibers
    - ACh (cholinergic)
  - SNS postganglionic fibers
    - NE (adrenergic)
  - PSN preganglionic & postganglionic fibers
    - ACh

**Neurotransmitters and Neuroreceptors of the ANS**

- 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 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 \( \rightarrow \) 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
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

Endorphin Response

- 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 NO₂ released from endothelial cells)

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
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 Fall 2012

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, DM
Aging and Hearing
- Cochlear hair cell degeneration
- Loss of auditory neurons in spiral ganglia of organ of Corti
- Degeneration of basilar conductive membrane of 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:

<table>
<thead>
<tr>
<th></th>
<th>4. Meniere disease</th>
<th>5. AMD</th>
<th>6. AOM</th>
<th>7. Sleep apnea</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>due to airway obstruction during breathing</td>
<td>Vestibular &amp; hearing disruption</td>
<td>Retinal detachment &amp; loss of photoreceptors</td>
<td>Effusion behind tympanic membrane</td>
</tr>
</tbody>
</table>

Matching:

- 8. Blepharitis A. Increase intraocular pressure
- 9. Vertigo B. Infected eyelid
- 10. Glaucoma C. Inflammation of semicircular canals

Alterations in Cognitive Systems, Cerebral Dynamics, & Motor Function
Chapter 14

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/may not 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 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

Parkinson Disease

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

Disorders of the Central & Peripheral Nervous Systems

Chapter 15

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

Brain Trauma

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

Subdural Hematomas

– collection of blood in closed space
**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

- Flexion-rotation injury

Spinal shock
- Normal activity of the SC ceases at and below the level of injury. Sites lack continuous nervous discharges from 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 US
  - Classified
    - Global hypoperfusion (as in shock)
    - Ischemia (thrombotic, embolic)
    - Hemorrhagic

Cerebrovascular Disorders

- 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 brain
  - Can also be from fat, tumor, bacteria, air
  - Middle cerebral artery is site of emboli

Cerebrovascular Disorders

- 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

- Due to: atherosclerosis, congenital, trauma, inflammation
- Pathophysiology: no single mechanism
- Classified: based on shape
- Clinical manifestations: asymptomatic or various cranial nerve compression, or hemorrhage

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 ACh 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: AChase 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

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

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