Chapter 14: The Brain

--largest organ in the body at almost 3 lbs
--brain functions in sensations, memory, emotions, decision making, behavior
--part of CNS contained in cranial cavity
--control center for many of body’s functions
--much like a complex computer but more

--Parts of brain
  a. brainstem
  b. cerebellum
  c. diencephalon
  d. cerebrum

--Developmental Anatomy of the NS
  *begins in 3rd week
    a. ectoderm forms thickening (NEURAL PLATE)
    b. plate folds inward to form NEURAL GROOV
    c. edges of folds join to form NEURAL TUBE
  *Neural crest tissue forms:
    a. spinal and cranial nerves
    b. dorsal root and cranial nerve ganglia
    c. adrenal gland medulla
  *layers of neural tube form:
    a. marginal layer which forms white matter
    b. mantle layer forms gray matter
    c. ependymal layer forms lining of cavities within NS
  *by end of 4th week, 3 anterior enlargements occur:
    a. prosencephalon (forebrain)
    b. mesencephalon (midbrain)
    c. rhombencephalon (hindbrain)
  *by 5th week, 5 enlarged areas exist
    a. prosencephalon: telencephalon, diencephalon
    b. mesencephalon
    c. rhombencephalon: metencephalon, myelencephalon
  *neural tube defects:
    a. associated with low levels of folic acid (B vitamins)
    b. spina bifida is failure of vertebrae to close
    c. anencephaly is absence of cranium and cerebral hemispheres

--Ventricles
  *Ventricles: lateral ventricles (2), third ventricle, fourth ventricle
  *Choroid plexus: produce CSF which fills ventricles and other parts of brain and spinal cord
    → blood-CSF fluid barrier: substances d/n pass b/w cells due to tight junctions of blood endothelial cells

--Principal Parts of the Brain
  *cerebrum
  *diencephalon: thalamus and hypothalamus
  *cerebellum
  *brainstem: medulla, pons, and midbrain

--Protective coverings of the Brain
*bone, meninges, and fluid
*meninges same as around spinal cord
*Spaces: subdural (serous fluid) and subarachnoid (CSF)
*Dura mater extensions: falx cerebri, tentorium cerebelli, falx cerebelli

--Brain Blood Supply
*requires tremendous amount of blood
*receives 15-20% of blood pumped by heart
*interruption can cause unconsciousness and irreversible brain damage
*high metabolic rate and dependence on constant supply of oxygen and glucose
*receives blood through arteries
*Blood-Brain barrier: capillary endothelial cells along with astrocytes and basement membrane, to be considered when developing drugs

--Blood Supply to Brain
*arterial blood supply is branches from circle of Willis on base of brain
*vessels on surface of brain—penetrate tissue
*uses 20% of our bodies oxygen and glucose needs
  a. blood flow to an area increases with activity in that area
  b. deprivation of oxygen for 4 min does permanent injury (at that time, lysosomes release enzymes)
*Blood Brain Barrier
  a. protects cells form some toxins and pathogens (proteins and antibiotics cannot pass but alcohol and anesthetics do)
  b. tight junctions seal together epithelial cells, continuous basement membrane, astrocyte processes covering capillaries

--CSF
*80-150 mL (3-5 oz)
*clear liquid containing glucose, few proteins, ions, few lymphocytes, oxygen, and carbon dioxide
*CSF = cell and protein free ultrafiltrate of plasma
*similar to blood plasma but without the plasma proteins
*Functions:
  a. mechanical protection: floats brain and softens impact with bony walls
  b. chemical protection: optimal ionic conc. for APs
  c. circulation: nutrients and waste products to and from bloodstream
*Origin:
  a. choroid plexus: capillaries covered by ependymal cells
    --2 lateral ventricles, roof of 3rd ventricle, 4th ventricle
*Drainage of CSF from Ventrices
  a. one median aperture and 2 lateral apertures allow CSF to exit from the interior of the brain
*Reabsorption: reabsorbed through arachnoid villi (grape like clusters of arachnoid penetrate dural venous sinus)
  a. 20 mL /hr reabsorption rate = same production rate = 480 mL/day
  b. when the CSF pressure exceeds the venous pressure, pressure-sensitive anatomical valves open allowing unidirectional drainage

--Hydrocephalus
*blockage of drainage of CSF (tumor, inflammation, developmental malformation, meningitis, hemorrhage, or injury)
*continued production cause an increase in pressure—hydrocephalus
*in newborn or fetus, the fontanels allow this internal pressure to cause expansion of the skull and lessens damage to the brain tissue

*neurosurgeon implants a drain shunting the CSF to the veins of the neck or the abdomen

*the CSF extends into the optic disk via the optic nerve → high CSF pressure elevates the optic disk above the retina (papilledema) –detected with an ophtalmoscope = diagnostic tool for CSF pressure

--Brainstem
*connects spinal cord to brain
*parts:
  a. medulla oblongata: regulates…
     - heart rate (CV center)
     - blood vessel diameter (vasomotor center)
     - respiration (rhythmicity center)
     - swallowing (deglutition)
     - vomiting (emesis)
     - hiccuping, coughing, sneezing
     - sensory tracts (recall decussation)
     - pyramids (direct motor pathways) decussate
  b. pons: regulates…
     - sleep
     - respiration center (apneustic and pneumotaxic)
  c. midbrain: regulates…
     - integral part of auditory pathways in CNS

--Medulla Oblongata
*continuation of spinal cord
*ascending sensory tracts
*descending motor tracts
*nuclei of 5 cranial nerves
*cardiovascular center: force and rate of heart beat, vasomotor center (diameter of blood vessels)
*respiratory center: medullary rhythmicity area sets basic rhythm of breathing
*information in and out of cerebellum
*reflex centers for coughing, sneezing, swallowing, etc.
*Ventral surface of Medulla Oblongata
  a. Ventral surface bulge: pyramids, large motor tract, decussation of most fibers (left cortex controls right muscles)
  b. Olive = olivary nucleus: neurons send input to cerebellum, proprioceptive signals, gives precision to movements

*Dorsal Surface of Medulla Oblongata
  a. nucleus gracilis and nucleus cuneatus: sensory neurons (relay info to thalamus on opposite side of brain)
  b. 5 cranial nerves arise from medulla (8-12)

*Injury to Medulla
  a. hard blow to the back of the head may be fatal
  b. cranial nerve malfunctions on same side as injury; loss of sensation or paralysis of throat or tongue; irregularities in breathing and heart rhythm

--Pons
*one inch long
*white fiber tracts ascend and descend
*pneumotaxic and apneustic areas help control breathing
*middle cerebellar peduncles carry sensory info to the cerebellum
*cranial nerves 5-8

--Midbrain
*one inch in length
*extends from pons to diencephalon
*cerebral aqueduct connects 3rd ventricle above to 4th ventricle below
*Cerebral peduncles: clusters of motor and sensory fibers

*Substantia nigra: helps controls subconscious muscle activity; dopamine secreting; loss of these leads to Parkinson’s
* Red nucleus: rich blood supply and iron containing pigment; cortex and cerebellum coordinate muscular movements by sending info here from the cortex and cerebellum

*Dorsal Surface of Midbrain
  a. corpora quadrigemina = superior and inferior colliculi
    -coordinate eye movements with visual stimuli (superior colliculi)
    -coordinate head movements with auditory stimuli (inferior colliculi)

--Reticular Formation
*scattered nuclei, both motor and sensory, in medulla, pons, and midbrain
*Sensory: Reticular activating system (RAS)
  a. alerts cerebral cortex to sensory signals (sound of alarm, flash light, smoke, or intruder) to awaken from sleep
  b. maintains consciousness and helps keep you awake with stimuli from ears, eyes, skin, and muscle
*Motor function: maintain muscle tone

--Cerebellum
*involved in control of: balance, posture, locomotion, and fine motor coordination producing smooth flowing movements
*2 cerebellar hemispheres and vermis (central area)
*Function: correct voluntary muscle contraction and posture based on sensory data from body about actual movements, sense of equilibrium
*transverse fissure b/w cerebellum and cerebrum (tentorium cerebelli)
*cerebellar cortex (folia) and central nuclei are gray matter
*arbor vitae = tree of life = white matter
*lobes: ant and post lobes = subconscious skeletal muscle movements
*floculonodular lobe: balance and equilibrium
*Cerebellar Peduncles
  a. Inferior: carries sensory info from spinal cord
  b. Middle: carries sensory fibers from cerebral cortex and basal ganglia
  c. Superior: carries motor fibers that extend to motor control areas

--Diencephalon
*Surrounds 3rd ventricle
*superior part of walls is thalamus
*inferior part of walls and floor is hypothalamus
*Components:
  a. Thalamus:
    -largest part of diencephalon
    -most sensory input projects to here
- influences mood and actions as fear or rage (survival emotions)

b. Subthalamus:
   - involved in controlling motor functions

c. Epithalamus:
   - pineal gland may influence sleep-wake cycle

d. Hypothalamus (homeostatic regulator)
   - ANS control
   - Endocrine control
   - Muscle control
   - Temperature regulation
   - Regulation of food and water intake
   - Emotions
   - Regulation of sleep-wake cycle

-- Thalamus
*1 inch long mass of gray mater in each half of brain (connected across the 3rd ventricle by intermediate mass)
* Relay station for sensory information on way to cortex
* Crude perception of some sensations (pain and temperature)
* Nuclei have different roles
   a. relays auditory and visual impulses, taste and somatic sensations
   b. receives impulse from cerebellum or basal ganglia
   c. anterior nucleus with emotions, memory, and acquisition of knowledge (cognition)

-- Hypothalamus
* dozen or so nuclei in 4 major regions
   a. mammillary bodies are relay station for olfactory reflexes; infundibulum suspends the pituitary gland
* major regulator of homeostasis
   a. Receives somatic and visceral input, taste, smell, and hearing information; monitors osmotic pressure, glucose conc., satiety and hunger centers, hormone levels, core body temp, endocrine

* Functions:
   a. controls and integrates activities of the ANS which regulates smooth, cardiac muscle, and glands
   b. synthesizes regulatory hormones that control the anterior pituitary
   c. contains cell bodies of axons that end in posterior pituitary where they secrete hormones
   d. regulates rage, aggression, pain, pleasure, and arousal
   e. feeding—thirst and satiety centers, hunger
   f. controls body temperature
   g. regulates daily patterns of sleep, intrinsic clock

* Nuclei of Hypothalamus
   a. posterior hypothalamus: shivering
   b. perifornical nucleus: hunger
   c. ventromedial nucleus: satiety
   d. arcuate nucleus and periventricular zone: neuroendocrine control
   e. lateralhypothalamic area: thirst and hunger
   f. paraventricular nucleus: oxytocin release
   g. posterior preoptic and anterior hypothalamic areas: body temperature regulation
   h. supraoptic nucleus: vasopressin release
--Epithalamus
  *pineal gland
    a. endocrine gland the size of small pea
    b. secretes melatonin during darkness (with lack of sympathetics)
    c. promotes sleepiness and sets biological clock
    d. habenular nuclei: emotional responses to odors

--Subthalamus and CVO
  *Subthalamus
    a. small area just inferior to thalamus
    b. work with basal ganglia, cerebrum, and cerebellum to control body movements
  *Circumventricular organs (CVO)
    a. in walls of 3rd and 4th ventricles
    b. monitor changes in blood chemistry because it lacks blood brain barrier (parts of hypothalamus, pineal, and pituitary gland)
    c. sites of entry of HIV virus into brain (dementia)

--Cerebrum
  *largest portion of brain
  *divisions: right, left
    a. longitudinal fissure separates left and right hemispheres
    b. corpus callosum is band of white matter connecting left and right cerebral hemispheres
  *Lobes: frontal, parietal, occipital, temporal, insula
  *Cortex: outer surface
    a. gray matter overlying white matter
    b. 2-4mm thick containing billions of cells
    c. grew so quickly formed folds (gyri) and grooves (sulci or fissures)
  *Medulla: center

--Cerebral White Matter
  *Association fibers: between gyri in same hemisphere
  *Commissural fibers: from one hemisphere to other
  *Projection fibers form descending and ascending tracts

--Basal Nuclei and Limbic System
  *Basal nuclei: motor function control
  *Limbic system: basic survival functions as memory, reproduction, nutrition, emotions

--Basal Ganglia
  *connections to red nucleus, substantia nigra, and subthalamus
  *input and output with cerebral cortex, thalamus, and hypothalamus
  *control large automatic movements of skeletal muscles

--Limbic system
  *parahippocampal and cingulated gyri and hippocampus
  *emotional brain-intense pleasure and intense pain
  *strong emotions increase efficiency of memory

--Brain Injuries
  *Causes of damage
    a. displacement or distortion of tissue at impact
    b. increased intracranial pressure
    c. infections
    d. free radical damage after ischemia
  *Concussion: temporary loss of consciousness (headache, drowsiness, confusion, lack of
*Contusion: bruising of brain (less than 5 min unconsciousness, blood in CSF)
*Laceration: tearing of brain (fracture or bullet), increased intracranial pressure from hematoma

--Sensory Areas of Cerebral Cortex
*receives sensory info form thalamus
*primary somatosensory area (post central gyrus)
*primary visual area
*primary gustatory area
*primary auditory area

--Motor Areas of Cerebral Cortex
*voluntary motor initiation: primary motor area (precentral gyrus)
*motor speech area: Broca’s area (production of speech—motor control of tongue and airway)

--Association Areas of Cerebral Cortex
a. somatosensory area: integrate and interpret
b. visual association area: recognize and evaluate
c. auditory association area (Wernicke’s): word become speech
d. Gnostic area: integrate all senses and respond
e. Premotor area: learned skilled movements such as typing
f. frontal eye field: scanning eye movement such as phone book

--Aphasia
*language area are located in the left cerebral hemisphere of most people
*Inability to use or comprehend words = aphasia
  a. nonfluent aphasia: inability to properly form words (know what want to say but cannot speak, damage to Broca’s)
  b. fluent aphasia: faulty understanding of spoken or written words (damage to Wernicke’s)
    -word deafness: inability to understand spoken word
    -word blindness: inability to understand written word

--Hemispheric Lateralization
*functional specialization of each hemisphere more pronounced in men
*females have larger connections between 2 sides
*Damage to left side: aphasia
*Damage to same area on right side produces speech with little emotional inflection

--Electroencephalogram (EEG)
*brain waves are millions of nerve APs in cerebral cortex
  a. diagnosis of brain disorders (epilepsy)
  b. brain death (absence of activity in 2 EEGs 24 hours apart)
*Alpha: awake and resting
*Beta: mental activity
*Theta: emotional stress  (brain disorders, degenerative brain state, normal in children)
*Delta: deep sleep (normal in awake infants, indicates brain damage in awake adults)

--Cerebrovascular Accident (CVA)
*third leading cause of death after heart attacks and cancer
* 2 types of stroke
  a. ischemic due to decreased blood flow
  b. hemorrhagic: due to rupture of blood vessel
*Risk factors: high blood pressure, high cholesterol, heart disease, diabetes, smoking, obesity, alcohol
*Tissue plasminogen activator (t-PA) used within 3 hours of onset will decrease permanent
disability
--Transient Ischemic Attack (TIA)
* episode of temporary cerebral dysfunction
* Cause: impaired blood flow to the brain
* Symptoms: dizziness, slurred speech, numbness, paralysis on one side, double vision
  --reach max intensity almost immediately
  --persists for 5-10 minutes and leaves no deficits
* Treatment is aspirin or anticoagulants; artery bypass grafting or carotid endarterectomy

--Alzheimer Disease (AD)
* dementia: loss of reasoning, ability to read, write, talk, eat, and walk
* afflicts 11% of population over 65
* loss of neurons that release ACh
* plaques of abnormal proteins outside neurons
* tangled protein filaments within neurons
* Risk factors: head injury, heredity
* beneficial effects of estrogen, vitamin E, ibuprofen, and ginko biloba

Sleep
--Sleep: state of unconsciousness from which the person can be aroused by sensory or other stimuli
--Coma: state of unconsciousness from which the person cannot be aroused by sensory stimuli
--Theories of Sleep:
  a. Old: excitatory areas (RAS) fatigue during the wakeful state
  b. Current: sleep is caused by an active inhibitory process
     * Evidence: transection of brain stem in midpons region creates a brain cortex that never
       sleeps. Thus, there is a “sleep center” below the midpons region that inhibits higher
       brain activity
--Factors Involved in Sleep:
  a. Location:
     i. raphe nuclei in lower pons and medulla: receives sensory input from the vagus and
        glossopharyngeal nerves from the viscera
     ii. Suprachiasmal area of hypothalamus and diffuse nuclei in thalamus
     * Brain lesions in raphe nuclei and suprachiasmal area of hypothalamus result in a high state of
       wakefulness (intense wakefulness in experimental animals to the point of death by exhaustion)
  b. Neurotransmitters
     i. Serotonin: blocking serotonin production with drugs causes loss of sleep for several days,
        however serotonin levels in blood are low during sleep
     ii. Muramyl peptide: substances in SCF, ruine, and blood from animals kept awake several
         days (have accumulated sleep promoting factors) are capable of inducing sleep when
         injected into the ventricular system of another animal
     iii. Adenosine: inhibits RAS activity, accumulates with high ATP use by brain; caffeine and
         theophylline block adenosine receptors
--Types of Sleep
a. NREM: slow wave
   *occurs soon after falling asleep, exceedingly restful, decreases in peripheral vascular tone, 10-30% decrease in blood pressure, respiratory rate, and basal metabolic rate; dreaming does occur but is not associated with muscle activity and is not remembered
b. REM: rapid eye movement
   *dreaming stages; 5-30 min at a time, about every 90 min. The deeper the sleep, the shorter the REM, As the person becomes more rested, the frequency and duration of REM increases
--Characteristics of REM
a. associated with active dreaming and active bodily muscle activity
b. person is even more difficult to arouse by sensory stimuli that during deep slow wave sleep
c. strong inhibition of spinal muscle tone control (severely depressed muscle tone)
d. heart and respiratory rate become irregular
e. rapid eye movements and irregular muscle movements occur
f. the brain is highly active (20% inc. in metabolism)
--Stages of Sleep
a. Stage 1: transitional between wakefulness and sleep
b. Stage 2: light sleep, some dreaming may occur
c. Stage 3: moderately deep sleep, about 20 min after falling asleep. BP, body temp dec, difficult to awaken
d. Stage 4: deepest sleep, decrease metabolism, but intact reflexes, sleepwalking occurs during this stage
--Physiological Effects of Sleep
   *Two Major Types
   a. On the nervous system: most pronounced; lack of sleep causes mental sluggishness and behavioral abnormalities (irritability, or even psychotic episodes)
   b. On other body systems (little)
   *Experiment: transect spinal cord in neck region—no input below the neck, observe no harmful effects below the level of transection
   *Effects of sleep on sympathetic and parasympathetic activity, metabolic rate, blood pressure, vasodilation
--Sleep Disorders
a. Cheyne Stokes Respiration (CSR): central (breathing pattern of increasing, then decreasing, then cessation of breathing again)
b. Narcolepsy
c. Sleep apnea:
   *Central sleep apnea: from normal pattern to no breathing (seconds to minutes), the back to normal
   *Obstructive sleep apnea: obstruction of airway
   **untreated sleep apnea is dangerous and may lead to hypertension, stroke, etc.
--Memory, Thoughts, Consciousness
a. Memory: formation of ‘memory traces’ in brain
   *changing synaptic transmission of specific neuronal pathways
   *limited ‘spinal’ memory also exists, spinal reflexes can be modified with repetitive activation
--Positive and Negative Memory
a. Negative memory: selective but substantial loss of information that is of inconsequential
significance. We are bombarded with sensory information, most of it is ignored (negative)
*inhibition of pathways is predominant
b. Positive memory: involves facilitation/sensitization of pathways from important stimuli

--Classification of Memory
a. Short term: last seconds to few minutes
   *reverberating circuits, presynaptic facilitation or inhibition
b. Intermediate long-term: days to weeks
   *chemical and physical changes of pre and/or post synaptic membranes
c. Long term: years to lifetime
   *inc. in number of NT vesicles, inc. in size of area over which NT is released, inc number of synapses

--Other Classifications
a. Working memory: short term memory used during intellectual activity but is lost when the activity is over
b. Declarative: memory of details of an experience
c. Skill memory: motor activity
d. Brain areas involved: HIPPOCAMPUS