The Brain and Cranial Nerves

Brain Function
- Primary organ of integration - reflex to thought
  - Acknowledgement of sensory input
  - Correlation with other information
    - Some of it stored (memory)
  - Decisions made about action
- Learning
- Creativity
- Communication
- Emotions

Anatomical Overview
- Brain stem
  - Medulla oblongata with fourth ventricle
  - Pons
  - Midbrain with cerebral aqueduct
  - Reticular formation
- Cerebellum
- Diencephalon separated by third ventricle
  - Hypothalamus
  - Thalamus
  - Pineal gland
- Cerebrum with paired lateral ventricles

Brain Diagram - Sagittal (graphic)
Brain Photo - Sagittal (graphic)

Development
- Ectodermal formation of neural plate, groove and tube
- Formation anterior of the primary vesicles (4th week)
  - Prosencephalon (fore)
  - Mesencephalon (mid)
  - Rhombencephalon (hind)
- Additional flexures forming secondary vesicles (5th week)
  - Prosencephalon divides into telencephalon (cerebrum and basal ganglia) and diencephalon
  - Mesencephalon (midbrain) no change
  - Rhombencephalon divides into metencephalon (pons and cerebellum) and myelencephalon (medulla)
- As brain continues to grow after birth, more neuroglia, dendritic outgrowths and synapses, and myelin (not nerve cells)

Brain – 4 Weeks (graphic)
Brain – 5 Weeks (graphic)
Ventricles (graphic)
Protection
• Cranial bones
• Meninges - dura mater, arachnoid and pia mater
  – Additional extensions of dura mater - falx cerebri, falx cerebelli and
tentorium cerebelli
  – Subarachnoid space contains major blood vessels and CSF
• Cerebrospinal fluid
Cranium Photo - Sagittal (graphic)
Meninges (graphic)
Cerebrospinal Fluid
• Fills all four ventricles
• Interventricular foramina and cerebral aqueduct
• Subarachnoid space - supplied through median aperture and paired lateral
  apertures in roof of 4th ventricle
• Provides both mechanical and chemical protection (favorable ion composition)
• Also serves as medium for diffusion of nutrients and wastes between brain and
  blood supply
Ventricles – 3D (graphic)
CSF Circulation
• Produced in choroid plexuses in ventricles - blood flow to walls of ventricles
  where ependymal cells receive plasma via filtration (fenestrated capillaries),
  and secrete CSF
  – Tight junctions between ependymal cells and selective secretion provide
    blood-CSF barrier - chemical protection
• Reabsorbed via arachnoid villi in dural venous sinuses, especially superior
  sagittal sinus
• Production and reabsorption rates the same - about 20 ml/hr (480 ml/day) of
  total of 80-150 ml
• Blockage of circulation slows reabsorption - hydrocephalus
  – Causes nerve cell damage
  – May require a drain to venous system
CSF Secretion (graphic)
CSF Flow (graphic)
Blood Supply
• Primarily from the cerebral arterial circle (circle of Willis)
  – L/R internal carotid and basilar via L/R vertebral (anastomoses)
• Continuous O₂ supply critical (brain uses 20% of O₂ supply while only 2% of
  body weight)
  – Deprivation of O₂ for 4 min. or more will cause cell damage
Continuous glucose supply also critical
- Primary source of ATP and little storage in cells

**Circle of Willis (graphic)**

**Blood-Brain Barrier**
- Endothelial cells of capillaries have tight junctions and are surrounded by basement membrane
  - What passes must go through cells
- Closely packed, surrounding astrocytes may also contribute
- Some molecules diffuse easily - gases, water, glucose and lipid soluble molecules (caffeine, nicotine, heroin, alcohol, many anesthetics, etc)
- Glucose by active transport
- Other molecules may pass slowly - most ions, urea, creatinine
- Still others, not at all - proteins, antibiotics
- Brain injury (trauma, inflammation, or toxin) may be associated with BBB damage - cause secondary complications

**BBB Bypass**
- Circumventricular organs (CVO)
- Important for blood monitoring and hormonal control secretions
  - BP, fluid balance, hunger, thirst
- Include pineal gland, pituitary gland, portion of hypothalamus
- Break in armor - may be site of HIV entry into brain resulting in dementia

**Medulla Oblongata**
- Contains all ascending sensory and descending motor tracts from spinal cord
  - Most cross-over (decussate) at this level
    - e.g. cerebral motor (skeletal) tracts pass through pyramids of medulla (anterior) and decussate before entering spinal cord
    - e.g. extensions of fasciculatus gracilis and cuneatus (of somatosensory posterior columns of cord) form nuclei gracilis and cuneatus, decussation may be at this level and pass to cerebrum via thalamus
- Includes nuclei which regulate certain vital functions
  - Cardiovascular center regulates heartbeat and blood vessel diameter
  - Medullary rhythmicity area regulates rate of respiration
  - Others for swallowing, vomiting, coughing, sneezing, and hiccupsing
- Olive nucleus - protrudes laterally
  - Connects with cerebellum via paired inferior cerebellar peduncles
  - Important for certain voluntary movements, equilibrium and posture (proprioceptors)
- Also includes nuclei from 5 of the 12 cranial nerves
  - Vestibulocochlear (VIII) - cochlear (hearing) portion to medulla
  - Glossopharyngeal (IX) - swallowing, salivation and taste
– Vagus (X) - innervation of thoracic and abdominal organs
– Accessory (XI)
  • Cranial portion from medulla - swallowing
  • Spinal portion - head and shoulder movement
– Hypoglossal (XII) - tongue movement

**Brain - Ventral (graphic)**

**Structures Within the Medulla (graphic)**

**Pons**
- Contains all ascending sensory and descending motor tracts from medulla to midbrain
- Includes transverse tracts that connect the two lobes of cerebellum - middle cerebellar peduncles
- Contains nuclei that aid in respiration - pneumotaxic and apneustic areas
- Also includes nuclei from 4 of the 12 cranial nerves
  - Trigeminal (V) - chewing and somatic sensation of head and face
  - Abducens (VI) - eye movement
  - Facial (VII) - taste, salivation and facial expression
  - Vestibulocochlear (VIII) - portions that control equilibrium

**Midbrain**
- Contains motor tracts from cerebral cortex to pons, medulla & cord; sensory tracts from medulla to thalamus - cerebral peduncle
- Includes nuclei for subconscious muscle control - substantia nigra
- Includes nuclei for muscle control with input from cerebellum and cerebrum - red nucleus
  - Iron-pigmented cell bodies
- Contains tracts between medulla (gracilis & cuneatus) and thalamus - medial lemniscus
  - Sensory information for discriminative touch, proprioception, pressure & vibration
- Include nuclei for reflex action to sensory input - tectum containing corpora quadrigemina (superior (visual) and inferior (auditory) colliculi)
- Also includes nuclei from 2 of the 12 cranial nerves
  - Oculomotor (III) - movement of eye, pupil and lens
  - Trochlear (IV) - movement of eye

**Structures Within the Midbrain (graphic)**

**Midbrain – Exterior (graphic)**

**Reticular Formation**
- Primarily a nuclei extending from cord to diencephalon (through whole of brain stem)
- Control of skeletal muscle and muscle tone
• Actuates cerebral cortex upon specific sensory input - reticular activating system

Cerebellum
• Lateral portions (cerebral hemispheres) separated by vermis
• Hemispheres organized into anterior and posterior lobes (primarily subconscious muscle control) and flocculonodular lobe (equilibrium)
• Cortex composed of gray matter; interior compose of white tracts and gray nuclei
• Connections to rest of brain via three cerebellar peduncles
  – Superior - motor info to midbrain
  – Middle - sensory info from pons
  – Inferior - sensory and motor to and from medulla and spinal cord
• Receives input about actual skeletal muscle movement, compares cerebral “intended” movement and adjusts motor output accordingly
  – Integrates state of equilibrium and posture with skeletal muscle contraction in process

Cerebellum - Exterior (graphic)

Cerebellum – Sagittal Section (graphic)

Diencephalon
• Epithalamus (single) including pineal gland (melatonin production affecting sleep and other cycles) and paired habenular nuclei (olfactory)
• Thalamus (paired)
• Subthalamus (paired) - motor control tracts and nuclei with connections to cerebrum
• Hypothalamus (paired)
• Circumventricular organs (previously reviewed)

Brain Diagram - Sagittal (graphic)

Thalamus
• 80% of diencephalon
• Integration (crude perception) and conduction of a variety of sensory input to cerebrum
  – Medial geniculate nucleus - hearing
  – Lateral geniculate nucleus - vision
  – Ventral posterior nucleus - taste, touch, pressure, vibration, heat, cold, and pain
• Integration of skeletal muscle information
  – Ventral lateral nucleus
  – Ventral anterior nucleus
• Some level of integration for emotions and memory
  – Anterior nucleus
• Communication between each via intermediate mass
Thalamic Nuclei (graphic)

Hypothalamus
- Reflexes to sense of smell - mammillary region
- Neural and hormonal communication with anterior pituitary - tuberal region
  - Includes infundibulum and medial eminence
- Visual information with neural communication to posterior pituitary
  (neurosecretion of oxytocin and antidiuretic hormone) - paraventricular & supraoptic region
- Partial regulation of autonomic action - preoptic region

Hypothalamic Nuclei (graphic)

Hypothalamic Control
- Autonomic control of visceral activity (heart rate, food movement, contraction of urinary bladder)
- Control of pituitary gland
- Various emotions (aggression, pain, & pleasure - including sexual arousal)
- Control of hunger and thirst
- Control of temperature
- Control of circadian (diurnal) patterns

Cerebrum
- L/R frontal, parietal, occipital & temporal lobes
- Cortical gray matter convoluted (protrusions - gyri, depressions - sulci or fissures)
- Transverse connection between lobes - corpus callosum
- Cerebral white matter conduct info to and from gray matter
  - Association fibers - between ipsilateral gyri
  - Commissural fibers - between corresponding contralateral gyri (via corpus callosum, anterior and posterior commissure)
  - Projection fibers - ascending and descending connections
- Basal ganglia (largely corpus striatum) - interconnected series of nuclei associated with cerebral cortex, thalamus and hypothalamus - extrapyramidal
  - Caudate nucleus and putamen coordinate automatic skeletal muscle movement
  - Globus pallidus controls muscle tone
  - Together globus pallidus and putamen make up the lentiform nucleus
- Limbic system - interconnected series of structures encircling the diencephalon and corpus callosum including gyri in the temporal lobe
  - Emotional brain - center for experience of emotions (pleasure, pain, anger, rage, fear, sorrow, sexual feelings, docility and affection)
  - Hippocampus important in memory association with emotion

Cerebral Lobes (graphic)
Cerebral White Matter (graphic)
Basal Ganglia (graphic)
Basal Ganglia – Section (graphic)
Limbic System (graphic)

Brain Injuries

- Related to rigidity and internal contours of skull, incompressibility of soft brain tissue and susceptibility to shearing forces (rapid acceleration or deceleration of head)
- Levels of damage
  - Concussion
    - Sudden loss of consciousness, no bruising, possible amnesia
  - Contusion
    - Extended loss of consciousness (minutes-hours), bruising with blood possibly getting below pia mater, possible neural damage
  - Laceration
    - Damage to brain with rupture of large blood vessels causing hematoma, neural damage, creates intracranial pressure, edema,
- Swelling of brain tissue forces tissue to expand through foramen magnum

Brain Aneurism (graphic)

Cortical Regions

- Gyri of cortex mapped according to types of sensory, motor or associative activities
- Language (audible)
  - Sensory - Primary auditory area (41, 42)
    - distinguishes characteristics of sound (e.g. pitch, rhythm)
  - Association - Auditory association area and Wernike’s area (22 and possibly 39, 40)
    - distinguishes between speech, music & noise, if speech, translates words to thoughts
    - integrates various sensory input
  - Motor speech area (Broca’s -44 &45) - 97% left side lateralization, right side important for tone of voice

Cortical Mapping (graphic)
Male Cortical Mapping (graphic)

Effects of Stroke

- Frequently associated with blood supply through middle cerebral artery which follows lateral cerebral sulcus
- Speech and language skills usually affected when on left side, little or no effect on right side
- Wernicke’s - difficulty speaking clearly and comprehending speech, difficulty reading, writing, naming objects & calculating
- Broca’s - difficulty speaking & sometimes writing
If left side, potentially right arm and leg paralysis (motor) or loss of sensation (sensory), loss of right visual field

**Lateralization**
- **Left lobe** - right-handed control
  - Spoken and written language
  - Numerical and scientific skills
  - Reasoning
- **Right lobe** - left-handed control
  - Musical and artistic awareness
  - Space and pattern perception
  - Insight
  - Imagination
  - Generating mental images to compare spatial relationships

**Lateralization Map (graphic)**

**It's in the Way You Write!**
- Non-inverted hand position - cerebral dominance opposite of handedness
- Inverted hand position - cerebral dominance same side as handedness
- Functional differences between left and right sides - lateralization
- Another way to tell - inject sodium amytal (barbiturate) into artery supplying either side, subject asked to count, inability to continue indicates dominant side

**Electroencephalogram**
- Combined electrical activity of the brain (AP’s and GP’s)
- Used for diagnosis of CNS disorders, sleep activity or brain inactivity
- Distinguished wave forms based on frequency (Hz)
  - **Alpha waves** - 8-13 Hz
    - Present when normal, awake, and resting
    - Absent during sleep
  - **Beta waves** - 14-30 Hz
    - Present when normal and active
  - **Theta waves** - 4-7 Hz
    - Present in children, adults under emotional stress, or possible brain disorders
  - **Delta waves** - 1-5 Hz
    - Present in infant, adults during normal deep sleep, or possible brain damage

**EEG Wave Types (graphic)**

**Cranial Nerves**
- On occasion, our trusty truck acts funny - very good vehicle anyhow.
- Olfactory (I) - sense of smell
  - test different types of odoriferous chemicals
• Optic (II)- visual information
  – test (for II, III, IV & VI) - while holding head still, track movement of finger
• Oculomotor (III) - eye lid and ball movement, iris control, proprioceptors
• Trochlear (IV)- also eye ball movement, proprioceptors
• Trigeminal (V)- chewing, sensations associated with chewing structures, proprioception
  – test - clench jaw, palpate for weak or flaccid muscle or light touch on forehead and side of face
• Abducens (VI)- also eye ball movement (lateral), proprioception
• Facial (VII)- facial expressions, salivation (not parotids), tearing
  – test - drooping of side of face
• Vestibulocochlear (VIII)- hearing, equilibrium
• Glossopharyngeal (IX)- salivation (parotids), taste, BP, proprioception for swallowing
  – test (for IX & X) - evaluate swallowing action

**Brain - Ventral (graphic)**

**Still More Cranial Nerves**
• Vagus (X)- smooth muscle contraction or relaxation, digestive secretions, visceral sensation, proprioception
• Accessory (XI)- swallowing (cranial), head movement (spinal), proprioception
  – test - shrug of shoulders
• Hypoglossal (XII)- tongue for speech & swallowing, proprioception
  – test - extension and side to side movement of tongue

**Effects of Aging**
• Neuronal loss
• Decreased conduction velocity
  – Slower voluntary movements
  – Slower reflexes
• Decline of sensory perception

**Disorders**
• On your own