Chapter 14
Brain
Cranial Nerves
Central Nervous System

- Overview of the brain
- Meninges, ventricles, cerebrospinal fluid and blood supply
- Hindbrain and midbrain
- Forebrain
- Higher forebrain functions
- The cranial nerves

(a) Superior view
Directional Terms and Landmarks

- **Rostral** (toward forehead) - **Caudal** (toward cord)
- **Major parts** - cerebrum, cerebellum, brainstem
  - cerebrum is 83% of brain volume; cerebellum contains 50% of the neurons
  - brain weighs 3 to 3.5 pounds
• Longitudinal fissure - cerebral hemispheres.
  – gyri = folds;  sulci = grooves
  – cortex = surface layer of gray matter
  – nuclei = deeper masses of gray matter
  – tracts = bundles of axons (white matter)
Lateral View of the Brain
Insula of Dissected Brain
Median Section of the Brain

- Cingulate gyrus
- Corpus callosum
- Frontal lobe
- Thalamus
- Anterior commissure
- Hypothalamus
- Optic chiasm
- Pituitary gland
- Temporal lobe
- Central sulcus
- Parietal lobe
- Parieto-occipital sulcus
- Occipital lobe
- Pineal gland
- Posterior commissure
- Cerebral aqueduct
- Fourth ventricle
- Cerebellum
- Midbrain
- Pons
- Medulla oblongata
Median Section of Cadaver Brain
Gray and White Matter

• Gray matter = neuron cell bodies, dendrites, and synapses
  – forms cortex over cerebrum and cerebellum
  – forms nuclei deep within brain

• White matter = bundles of axons
  – forms tracts that connect parts of brain
Embryonic Development

• Nervous system develops from ectoderm
  – by 3rd week, neural plate becomes a groove with neural folds along each side
  – by 4th week, neural folds join to form neural tube
  – lumen of the neural tube develops into central canal of spinal cord and ventricles of the brain
  – cells along the margin of the neural groove is called the neural crest
    • develop into sensory and sympathetic neurons and schwann cells
  – by 4th week, neural tube exhibits 3 anterior dilations
Embryonic Neural Tube

Neural plate
Neural crest
Ectoderm
Notochord

19 days

Neural groove
Neural crest
Neural fold

20 days

22 days

Neural crest
Neural tube
Somites

26 days
Embryonic Brain Development

• 4th week
  – forebrain
  – midbrain
  – hindbrain

• 5th week
  – telencephalon
  – diencephalon
  – mesencephalon
  – metencephalon
  – myelencephalon
Meninges

• Dura mater -- outermost, tough membrane
  – outer periosteal layer against bone
  – where separated from inner meningeal layer forms dural venous sinuses draining blood from brain
  – supportive structures formed by dura mater
    • falx cerebri, falx cerebelli and tentorium cerebelli
  – epidural space filled with fat in low back
    • epidural anaesthesia during childbirth

• Arachnoid and pia mater – as in spinal cord
  – subarachnoid and subdural spaces
Meninges of the Brain

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Brain Ventrices
Ventricles of the Brain
Ventricles and Cerebrospinal Fluid

• Internal chambers within the CNS
  – lateral ventricles in cerebral hemispheres
  – third ventricle = single vertical space under corpus callosum
  – cerebral aqueduct runs through midbrain
  – fourth ventricle = chamber between pons and cerebellum
  – central canal runs down through spinal cord
• Lined with ependymal cells
• Choroid plexus produce CSF
Cerebrospinal Fluid

• Fills ventricles and subarachnoid space
• Brain produces and absorbs 500 ml/day
  – choroid plexus creates by filtration of blood
• Functions
  – floats brain so it is neutrally buoyant
  – cushions from hitting inside of skull
  – chemical stability -- rinses away wastes
• Escapes (4th ventricle) to surround brain
• Absorbed into venous sinus by arachnoid villi
Flow of Cerebrospinal Fluid

1. CSF is secreted by choroid plexus in each lateral ventricle.
2. CSF flows through interventricular foramina into third ventricle.
3. Choroid plexus in third ventricle adds more CSF.
4. CSF flows down cerebral aqueduct to fourth ventricle.
5. Choroid plexus in fourth ventricle adds more CSF.
6. CSF flows out two lateral apertures and one median aperture.
7. CSF fills subarachnoid space and bathes external surfaces of brain and spinal cord.
8. At arachnoid villi, CSF is reabsorbed into venous blood of dural venous sinuses.
Blood-brain barrier is endothelium
- permeable to lipid-soluble materials
  • alcohol, O₂, CO₂, nicotine and anesthetics
- circumventricular organs
  • in 3rd and 4th ventricles are breaks in the barrier where blood has direct access
  • monitors glucose, pH, osmolarity and others
  • route for HIV virus to invade the brain

Blood-CSF barrier at choroid plexus is ependymal cells joined by tight junctions
Hindbrain - Medulla Oblongata

- 3 cm extension of spinal cord
- Ascending and descending nerve tracts
- Nuclei of sensory and motor CNs (IX, X, XI, XII)
- Pyramids and olive visible on surface
Hindbrain - Medulla Oblongata

- **Cardiac center**
  - adjusts rate and force of heart
- **Vasomotor center**
  - adjusts blood vessel diameter
- **Respiratory centers**
  - control rate and depth of breathing
- **Reflex centers**
  - for coughing, sneezing, gagging, swallowing, vomiting, salivation, sweating, movements of tongue and head
Medulla Oblongata

- Gracile nucleus
- Cuneate nucleus
- Dorsal spinocerebellar tract
- Reticular formation
- Medial lemniscus
- Hypoglossal nerve
- Pyramidal tract
- Nucleus of hypoglossal nerve
- Fourth ventricle
- Nucleus of vagus nerve
- Trigeminal nerve: Nucleus, Tract
- Tectospinal tract
- Inferior olivary nucleus
- Olive
- Pyramids of medulla

(c) Medulla oblongata
Medulla and Pons
Dorsolateral View of Brainstem
• Bulge in brainstem, rostral to medulla
• Ascending sensory tracts
• Descending motor tracts
• Pathways in and out of cerebellum
Pons

- **Nuclei**
  - concerned with posture, sleep, hearing, balance, taste, eye movements, facial expression, facial sensation, respiration, swallowing, and bladder control
  - cranial nerves V, VI, VII, and VIII
Cross-section of Pons

(b) Superior view
Cerebellum

- Two hemispheres connected by vermis
- Cortex = surface folds called folia
- Output comes from deep gray nuclei
  - granule and purkinje cells
Cerebellum

- Sits atop 4th ventricle
- White matter (arbor vitae) visible in sagittal section
- Connected to brainstem by cerebellar peduncles
  - superior peduncle = output to midbrain, thalamus, and cortex
  - middle peduncle = input from cerebral cortex and inner ear
  - inferior peduncle = spinocerebellar tracts (proprioception)
Cerebellar Functions

• Evaluation of sensory input
  – coordination and locomotor ability
  – spatial perception
• Timekeeping center
  – predicting movement of objects
• Distinguish pitch and similar sounding words
• Planning and scheduling tasks
Midbrain -- Cross Section

• Central aqueduct
• CN III and IV
  – eye movement
• Cerebral peduncles
  – hold corticospinal tract
Midbrain - Cross Section

• Tegmentum
  – connects to cerebellum and helps control fine movements through red nucleus

• Substantia nigra
  – sends inhibitory signals to basal ganglia and thalamus (degeneration leads to tremors and Parkinson disease)

• Central gray matter = pain awareness
Superior and Inferior Colliculus

- Tectum (4 nuclei - corpora quadrigemina)
  - superior colliculus (tracks moving objects, blinking, pupillary and head turning reflexes)
  - inferior colliculus (reflex turning of head to sound)
Reticular Formation
Reticular Activating System

• Clusters of gray matter scattered throughout pons, midbrain and medulla
• Regulate balance and posture
  – relays information from eyes and ears to cerebellum
  – gaze centers and central pattern generators
• Includes cardiac and vasomotor centers
• Origin of descending analgesic pathways
• Regulates sleep and conscious attention (habituation)
  – injury leads to irreversible coma
Diencephalon: Thalamus

- Oval mass of gray matter protrudes into lateral ventricle and 3rd ventricle
- 23 nuclei receive nearly all sensory information on its way to cerebral cortex
- Relays signals from cerebellum to motor cortex
- Emotional and memory functions
Diencephalon: Hypothalamus

- Walls and floor of 3rd ventricle
- Functions
  - hormone secretion
  - autonomic NS control
  - thermoregulation
  - food and water intake (hunger and satiety)
  - sleep and circadian rhythms
  - memory (mammillary bodies)
  - emotional behavior
Diencephalon: Hypothalamus

- Mammillary bodies contain 3 to 4 nuclei that relay signals from limbic system to thalamus
Diencephalon: Epithalamus

Epithalamus consists of pineal gland (endocrine) and the habenula (connects limbic system to midbrain)
Cerebral cortex - 3mm layer of gray matter
  - extensive folds increase surface area - divided into lobes
Functions of Cerebrum - Lobes

• Frontal
  – voluntary motor functions
  – planning, mood, smell and social judgement

• Parietal
  – receives and integrates sensory information

• Occipital
  – visual center of brain

• Temporal
  – areas for hearing, smell, learning, memory, emotional behavior
Tracts of Cerebral White Matter
Tracts of Cerebral White Matter

• Most of cerebrum is white matter
• Types of tracts
  – projection tracts
    • from brain to spinal cord, forms internal capsule
  – commissural tracts
    • cross to opposite hemisphere
      – corpus callosum
      – anterior and posterior commissures
  – association tracts
    • connect lobes and gyri within a hemisphere
Cerebral Cortex

- Surface layer of gray matter -- 3 mm thick
- Neocortex (six-layered tissue)
  - newest part (paleocortex and archicortex)
  - layers vary in thickness in different regions
- 2 types of cells
  - stellate cells
    - dendrites project in all directions
  - pyramidal cells
    - axon passes out of the area
Basal Nuclei

- Masses of gray matter deep to cortex
  - corpus striatum (lentiform nucleus) = caudate nucleus, putamen, and globus pallidus
- Motor control
  - substantia nigra and motor cortex
Limbic System

- Loop of cortical structures
  - amygdala, hippocampus and cingulate gyrus
- Role in emotion and memory
  - pleasure and aversion centers
EEG and Brain Waves

- **Electroencephalogram**
  - records voltage changes from postsynaptic potentials in cerebral cortex

- **Brain waves**
  - 4 types distinguished by amplitude and frequency
Brain Waves

- **alpha**
  - occur when awake; resting with eyes closed
- **beta**
  - eyes open; performing mental tasks
- **theta**
  - sleep or emotional stress
- **delta**
  - deep sleep
Sleep

• Temporary state of unconsciousness
  – sleep paralysis = inhibition of muscular activity
  – suprachiasmatic nucleus acts as biological clock to set our circadian rhythm

• Controlled by hypothalamus, reticular formation, thalamus, and cerebral cortex

• Restorative effect
  – brain glycogen levels increase
  – memories strengthened
    • synoptic connections reinforced or eliminated
Stages of Sleep

• Non-REM sleep
  – stage 1 - drifting sensation (claim not sleeping)
  – stage 2 - light sleep
  – stage 3 vital signs change -- BP, pulse and breathing rates drop
    • reached in 20 minutes
  – stage 4 is deep sleep -- difficult to arouse

• REM sleep
  – rapid eye movements under eyelids, vital signs increase, EEG resembles awake person, dreams and penile erections occur
Sleep Stages

- Brain waves change during sleep phases and cycles
Cognition

• Mental processes
  – such as awareness, perception, thinking, knowledge and memory
  – association areas = 75% of brain
    • integration of sensory and motor information occurs
Brain lesions

- **parietal lobe**
  - contralateral neglect syndrome
- **temporal lobe**
  - agnosia - inability to recognize objects
  - prosopagnosia - inability to recognize faces
- **frontal lobe**
  - problems with personality (inability to plan and execute appropriate behavior)
Memory

• Information management
  – requires learning, memory and forgetting

• Amnesia
  – anterograde amnesia - no new memories
  – retrograde amnesia – can’t remember old ones

• Hippocampus
  – organizes sensory and cognitive information into a new memory

• Cerebellum – helps learn motor skills

• Amygdala - emotional memory
Emotion

• Prefrontal cortex
  – controls expression of emotions

• Form in hypothalamus and amygdala
  – fear, anger, pleasure, love, etc.
  – electrode in median forebrain bundle
    • press foot pedal all day to the exclusion of food
      (report a quiet, relaxed feeling – relief from tension)

• Behavior
  – often learned by rewards and punishments or responses of others
Somesthetic Sensation

• Receptors
  – for touch, pressure, stretch, temperature, and pain
• Gracile and cuneate fasciculi and spinothalamic tracts
  – ascending signals decussate, go to thalamus, to cortex
• Somatosensory area in postcentral gyrus
Sensory Homunculus

• Area of cortex dedicated to sensations of body parts is proportional to the sensitivity of that body part (# of receptors)
• Somatotopy
Functional Regions of Cerebral Cortex

Primary somesthetic cortex

Somesthetic association area

Primary gustatory cortex

Wernicke area

Visual association area

Primary visual cortex

Primary auditory area

Auditory association area

Primary motor cortex

Motor association area

Broca area

Prefrontal cortex

Olfactory association area
Special Senses

- Organs of special senses project to specialized regions of the brain
- Taste - lower end of postcentral gyrus
- Smell - medial temporal lobe and inferior frontal lobe
- Vision - occipital lobe
- Hearing - superior temporal lobe
- Equilibrium - cerebellum and lateral and central sulcus (via thalamus)
Sensory Association Areas

• Interpret sensory information
• Somesthetic association area (parietal lobe)
  – position of limbs; location of touch or pain;
    shape, weight and texture of an object
• Visual association area (occipital lobe)
  – identify things we see
  – faces recognized in temporal lobe
• Auditory association area (temporal lobe)
  – recall the name of a piece of music or identify a person by his voice
Motor Control

- Intention to contract a muscle begins in motor association (premotor) area of frontal lobes.
- Precentral gyrus (primary motor area) relays signals to spinal cord.
  - Pyramidal cells called upper motor neurons.
  - Supply muscles of contralateral side.
- Motor homunculus - proportional to number of muscle motor units in a region.
Motor Homunculus
Basal Nuclei and Cerebellum

• Basal nuclei in feedback circuit with cerebral cortex
  – highly practised movements
  – starting and stopping movements
  – walking
  – dyskinesias and unwanted movements

• Cerebellum
  – learned motor skills, muscle tone, posture, and smooth muscle contractions
  – compares intention to actual movement and sends signal to adjust
Input and Output to Cerebellum
Language

- Includes reading, writing, speaking and understanding words
- Wernicke area
  - permits recognition of spoken and written language and creates plan of speech
- Broca area
  - generates motor signals for larynx, tongue, cheeks and lips
  - transmits to primary motor cortex for action
- Affective language area lesions produce aprosodia
Lateralization of Cerebral Functions

<table>
<thead>
<tr>
<th>Left hemisphere</th>
<th>Right hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olfaction, right nasal cavity</td>
<td>Olfaction, left nasal cavity</td>
</tr>
<tr>
<td>Verbal memory</td>
<td>Memory for shapes</td>
</tr>
<tr>
<td>Speech</td>
<td>(Limited language comprehension, mute)</td>
</tr>
<tr>
<td>Right hand motor control</td>
<td>Left hand motor control</td>
</tr>
<tr>
<td>Feeling shapes with right hand</td>
<td>Feeling shapes with left hand</td>
</tr>
<tr>
<td>Hearing vocal sounds (right ear advantage)</td>
<td>Hearing nonvocal sounds (left ear advantage)</td>
</tr>
<tr>
<td>Rational, symbolic thought</td>
<td>Musical ability</td>
</tr>
<tr>
<td>Superior language comprehension</td>
<td>Intuitive, nonverbal thought</td>
</tr>
<tr>
<td>Vision, right field</td>
<td>Superior recognition of faces and spatial relationships</td>
</tr>
<tr>
<td></td>
<td>Vision, left field</td>
</tr>
</tbody>
</table>
Cerebral Lateralization

• Left hemisphere - categorical hemisphere
  – specialized for spoken and written language, sequential and analytical reasoning (math and science), analyze data in linear way

• Right hemisphere - representational hemisphere
  – perceives information more holistically, perception of spatial relationships, pattern, comparison of special senses, imagination and insight, music and artistic skill

• Highly correlated with handedness
  – 91% of people right-handed are left side dominant

• Lateralization develops with age
  – females have more communication between hemispheres (corpus callosum thicker posteriorly)
Cranial Nerves

• 12 pair of nerves
  – arise from brain
  – exit through foramina leading to muscles, glands and sense organs in head and neck

• Input and output ipsilateral except CN II and IV
I. Olfactory Nerve

- Sense of smell
- Damage causes impaired sense of smell
II. Optic Nerve

- Provides vision
- Damage causes blindness in visual field
III. Oculomotor Nerve

- Eye movement, opening of eyelid, constriction of pupil, focusing
- Damage causes drooping eyelid, dilated pupil, double vision, difficulty focusing and inability to move eye in certain directions
IV. Trochlear Nerve

- Eye movement (superior oblique muscle)
- Damage causes double vision and inability to rotate eye inferolaterally
V. Trigeminal Nerve

- Sensory to face (touch, pain and temperature) and muscles of mastication
- Damage produces loss of sensation and impaired chewing
VI. Abducens Nerve

- Provides eye movement (lateral rectus m.)
- Damage results in inability to rotate eye laterally and at rest eye rotates medially
VII. Facial Nerve

- **Motor** - facial expressions; salivary glands and tear, nasal and palatine glands
- **Sensory** - taste on anterior 2/3’s of tongue
- **Damage** produces sagging facial muscles and disturbed sense of taste (no sweet and salty)
Branches of Facial Nerve

Clinical test: Test anterior 2/3’s of tongue with substances such as sugar, salt, vinegar, and quinine; test response of tear glands to ammonia fumes; test motor functions by asking subject to close eyes, smile, whistle, frown, raise eyebrows, etc.
VIII. Vestibulocochlear Nerve

- Provides hearing and sense of balance
- Damage produces deafness, dizziness, nausea, loss of balance and nystagmus
IX. Glossopharyngeal Nerve

- Swallowing, salivation, gagging, control of BP and respiration
- Sensations from posterior 1/3 of tongue
- Damage results in loss of bitter and sour taste and impaired swallowing
X. Vagus Nerve

- Swallowing, speech, regulation of viscera
- Damage causes hoarseness or loss of voice, impaired swallowing and fatal if both are cut
XI. Accessory Nerve

- Swallowing, head, neck and shoulder movement
  - damage causes impaired head, neck, shoulder movement; head turns towards injured side
XII. Hypoglossal Nerve

- Tongue movements for speech, food manipulation and swallowing
  - if both are damaged – can’t protrude tongue
  - if one side is damaged – tongue deviates towards injured side; see ipsilateral atrophy