Central Nervous System
Brain and Spinal Cord

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Brain

- Major regions
  - Cerebrum
  - Diencephalon
  - Brainstem
  - Cerebellum
Terminology

- **Gray matter**
  - Unmyelinated regions
- **White matter**
  - Myelinated axons
- **Cerebral hemispheres**
  - Left and right halves
  - Separated by longitudinal fissure
  - Connected in spots by tracts
Meninges

- Covered by 3 connective tissue layers = meninges
  - Dura mater
  - Arachnoid mater
  - Pia mater
• "tough mother"
  - dense connective tissue
  - outer, double layered surrounding the brain
    • outer = periossteal layer
    • inner = meningeal layer (folded in certain locations as a "falx")
  - openings between the 2 layers are dural sinuses
Meninges: Arachnoid mater

- “spidery mother”
- contains villi for return of CSF to general circulation
- network of connective tissue
Meninges:

Pia mater

• “delicate mother”
• indissectible from surface of the CNS
• loose connective tissue
Hemorrhages

• **Epidural**
  - **General**
    • 1% of head injuries
    • Mortality 100% if untreated, 50% with treatment
  - **Arterial break**
    • Quickly forces large amounts of blood into epidural space
    • Unconscious in minutes to hours
  - **Venous break**
    • Slow loss of consciousness ranging from hours to weeks
Epidural hematoma
Hemorrhages

- **Subdural**
  - Meningeal layer of dura
  - Usually from small vein or dural sinuses
  - Variable effects due to low blood pressure
Subdural hemorrhage
Ventricles

- **Lateral ventricles**
  - 2 ventricles shaped like “ram horns”
  - inferior, medial to cerebral hemispheres
- **Third ventricle**
  - surrounded by diencephalon of brain stem
- **Fourth ventricle**
  - anterior to cerebellum
  - contains 3 apertures leading to the “subarachnoid space”
  - (2 lateral and 1 median)
Ventricles & Central Canal

- Cerebral aqueduct
  - canal between third and fourth ventricle
- central canal
  - centrally located in the spinal cord
- ventricles lined with choroid plexus and ependymal cells
  - cerebrospinal fluid production
- cerebrospinal fluid circulates throughout ventricles, central canal and subarachnoid space
- returns to general circulation through arachnoid villi at dural sinuses
Ventricles & Central Canal
1. CSF is secreted by choroid plexus in each lateral ventricle.
2. CSF flows through inter-ventricular 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 resorbed into venous blood of dural venous sinuses.
Hydrocephalus
Treatment of hydrocephalus
Cerebrum

- Cerebral cortex
- contains “higher brain centers”
- nuclei responsible for motor coordination and control of memory, emotion and other functions
- Cerebral hemispheres
General structures of gray matter (cortex)

- gyrus (gyri p.)
  - folds of the cerebral surface
- sulcus (sulci p.)
  - grooves between gyri
- Fissure
  - deep groove
Lobes of cerebral cortex

• 5 major divisions in each hemisphere
• 4 named after bones above them
  - Frontal
  - Parietal
  - Occipital
  - Temporal
• 1 on interior
  - Insula
Frontal lobe

- Anterior portion of brain
- bordered posteriorly by the central sulcus and inferiorly by lateral sulcus
- Contains motor cortex
  - precentral gyrus
  - contains pyramidal neurons that “plan” motor activity
Parietal lobe

- posterior to the central sulcus
- anterior to the lateral sulcus
- separated from the occipital lobe by the parieto-occipital sulcus
- Contains sensory cortex
  - postcentral gyrus
  - responsible for sensory "perception"
Occipital & Temporal lobes

- **Occipital**
  - posterior most lobe
  - visual cortex

- **Temporal**
  - lateral lobes
  - inferior to the lateral sulcus
Insula

- Small lobes deep in lateral sulcus beneath temporal lobes
- Function: memory and interpretation of taste

New study suggests that the insula may be involved in smoking addiction...

Congenital hydranencephaly

- Rare genetic abnormality
- Cerebral hemispheres are absent and replaced with sacks containing CSF
- Appear relatively normal at birth
- Usually do not survive past first birthday
Functional areas of brain

- **Motor areas**
  - Control voluntary movement
- **Sensory areas**
  - Conscious awareness of sensation
- **Association areas**
  - Integrate and store information
Homunculus

(a) Left hemisphere
- Frontal lobe
- Central sulcus
- Parietal lobe
- Occipital lobe

(b) Right hemisphere
- Precentral gyrus
- Postcentral gyrus

(c) Homunculus:
- Face
- Lips
- Jaw
- Tongue
- Throat
- Hand
- Wrist
- Finger
- Thumb
- Neck
- Head
- Eye
- Ear
- Mouth
- Tongue
- Swallowing
- Salivation
- Vocalization
Cerebral lateralization

Olfaction, right nostril
Verbal memory
Speech
Right hand motor control
Feeling shapes with right hand
Hearing vocal sounds (right ear advantage)
Rational, symbolic thought
Superior language comprehension
Vision, right field

Olfaction, left nostril
Memory for shapes
(Limited language comprehension, mute)
Left hand motor control
Feeling shapes with left hand
Hearing non-vocal sounds (left ear advantage)
Musical ability
Intuitive, nonverbal thought
Superior recognition of faces and spatial relationships

Frontal
Left hemisphere
Parietal
Right hemisphere
Vision, left field
Disconnection syndrome

- Surgical separation of the corpus callosum to treat severe seizures
- Two hemispheres function independently
- Initial response reflects loss of brain function
  - Objects touched by left hand are recognized, cannot be verbally identified...why
- Brain adapts by increasing info sent across anterior commissure
Corpus callosotomy
Cerebral white matter tracts

• Association tracts
  - Connect regions of cortex within same hemisphere

• Commissural tracts
  - Bridges between cerebral hemispheres
  - Ex) corpus callosum

• Projection tracts
  - Between cerebral cortex, caudal brain, and spinal cord
Association tracts
Frontal lobe
Corpus callosum
Temporal lobe (a)
Longitudinal fissure
Corpus callosum
Basal nuclei
Cerebral peduncle
Projection tracts
Decussation in pyramids (b)
Projection tracts
Parietal lobe
Occipital lobe
Commisural tracts
Lateral ventricle
Thalamus
Third ventricle
Mammillary body
Pons
Pyramid
Medulla oblongata

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Basal nuclei

- Paired, irregular masses of gray matter within white matter in basal region of cerebral hemispheres
- Caudate nucleus
- Amygdala
- Putamen & globus pallidus
- Claustrum
Basal nuclei
Diencephalon

• “in-between” brain
• Components
  – Epithalamus
  – Thalamus (right and left)
  – hypothalamus
• Functions
  – Relay and switching station for certain sensory and motor pathways
  – Control visceral activities
DIENCEPHALON:
- Thalamus
- Hypothalamus
- Epithalamus
- Pineal gland

BRAIN STEM:
- Midbrain
- Pons
- Medulla oblongata
- Infundibulum
- Pituitary gland

CEREBELLUM

Spinal cord

POSTERIOR

ANTERIOR
Epithalamus

- Covers 3rd ventricle
- contains choroid plexus and ependymal cells producing CSF and the pineal gland
- Posterior portion
  - Pineal gland
    - Melatonin
    - Circadian rhythms
  - Habenular nucleus
    - Relay station for limbic system
    - Visceral and emotional response to odors
Thalamus

- Clusters of nuclei organized into groups
- Major relay station for sensory information
- Gray matter on both sides of third ventricle
hypothesis

- contains many diverse nuclei controlling body temperature, sex drive, feeding, drinking, thirst sensation, pituitary secretions
- forms the inferior walls of the third ventricle
Thalamus

- Lateral group: Somesthetic input to association areas; contributes to limbic system
- Medial group: Emotional input to prefrontal cortex; awareness of emotions
- Ventral group: Somesthetic input to postcentral gyrus; signals from cerebellum and basal nuclei to primary motor and motor association areas
- Anterior group: Part of limbic system
- Lateral geniculate nucleus: Visual signals to occipital lobe

Hypothalamus

- Mammillary body: Relays signals from limbic system to thalamus
- Paraventricular nucleus: Produces oxytocin (involved in childbirth, lactation, orgasm); autonomic motor effects; control of posterior pituitary
- Anterior nucleus: Thirst center
- Ventromedial nucleus: Satiety center (suppresses hunger); emotion
- Preoptic nucleus: Thermoregulation; control of female reproductive cycle; sexual behavior
- Supraoptic nucleus: Produces antidiuretic hormone (involved in water conservation); control of posterior pituitary
- Suprachiasmatic nucleus: Biological clock; regulates circadian rhythms and female reproductive cycle

Intermediate mass

Optic chiasm
Optic nerve
Pituitary gland
Brain Stem

- Connects forebrain and cerebellum to spinal cord
- 3 parts
  - Mesencephalon (midbrain)
  - Metencephalon (Pons)
  - Myelencephalon (Medulla oblongata)
Mesencephalon

- **Visual/auditory reflexes, arousal, motor coordination**
- **Cerebral peduncles**
  - Motor tracts, including part of corticospinal tract
- **Substantia nigra**
  - Nuclei that relay inhibitory signals to cerebellar nuclei
  - Modify motor responses
- **Tegumentum**
  - Red nuclei
  - Information integration between cerebrum and cerebellum
  - Involuntary motor commands in erector spinae assoc with posture
- **Tectum**
  - Sensory nuclei = Corpora quadrigemina
    - superior colliculi (visual reflexes)
    - inferior colliculi (auditory reflexes)
Pons

- Contains sensory and motor tracts
- Autonomic respiratory center
  - Pneumotaxic center
  - Apneustic center
- Origin for many cranial nerves (V-VIII)
Medulla oblongata

- Decussation of pyramids
- the inferior most region of the brain stem
- Nuclei controlling additional respiratory functions, cardiac, vomiting
- origin of many cranial nerves
Reticular Formation

- a loose network of neurons the project from the brain stem (found in all areas) to the cerebral cortex
- function to arouse the cortex to incoming sensory stimuli
Limbic System

• a large group of nuclei, inferior to the corpus callosum
• responsible for control of emotion, sex drive, aggression, memory consolidation among other functions
• Includes
  - Hippocampus
  - Amygdala
  - Cingulate gyrus
  - Fornix
  - Hypothalamus
  - Thalamus
Limbic System

- Medial prefrontal cortex
- Corpus callosum
- Cingulate gyrus
- Orbitofrontal cortex
- Basal nuclei
- Amygdala
- Temporal lobe
- Thalamic nuclei
- Mammillary body
- Hippocampus
Cerebellum

• the second largest single structure of the brain
• Three lobes
  - Anterior
  - Posterior
  - flocculonodular (small)
Anatomy of the cerebellum

- **arbor vitae**
  - “the tree of life”
  - white matter (axon tracts) of the cerebellum
  - cerebellar cortex folded into many plate-like ridges called “folia”

- **Vermis**
  - narrow band of cortex that separates the anterior and posterior lobes
CEREBELLAR PEDUNCLES:
- SUPEROIOR
- MIDDLE
- INFERIOR

ANTERIOR

POSTERIOR

(b) Inferior view

FLOCCULO-NODULAR LOBE

VERMIS

POSTERIOR (MIDDLE) LOBE

CEREBELLAR HEMISPHERE

Fourth ventricle

Inferior
Spinal Cord
Gross Anatomy

- Size: 42-45 cm long
- Regions
  - Cervical
    - Continuous with medulla oblongata
    - Motor neurons form cervical spinal nerves
  - Thoracic
    - Motor neurons form thoracic spinal nerves
  - Lumbar
    - Motor neurons for lumbar spinal nerves
  - Sacral
    - Motor neurons for sacral spinal nerves
  - Coccygeal

Note: doesn't match up exactly to vertebrae
Regions

- **Cervical enlargement**
  - Innervates upper limbs

- **Lumbar enlargement**
  - Innervates lower limbs

- **Conus medullaris = end of the spinal cord**
  - **Cauda equina = axons**
  - **Filum terminale = pia mater that anchors conus medullaris to coccyx**
1. Comus medullaris
2. Iliohypogastric nerve
3. Pelviureteric junction
4. Ilioinguinal nerve
5. Posterior surface of right kidney
6. Lateral cutaneous nerve of thigh
7. Cauda equina
8. Descending colon
Meninges

- Pia mater
- Subarachnoid space
  - CSF
  - Site of lumbar puncture
- Arachnoid mater
- Dura mater
  - Only one layer
- Epidural space
Cross sectional anatomy
Meninges
Cross section

- Cross sectional anatomy differs in each region
- Shape in xs
  - Cylindrical with posterior and anterior flattening
  - Two longitudinal depressions
    - Posterior (dorsal) median sulcus
    - Anterior (ventral) median fissure
• areas of gray matter
• **anterior gray horn**
  - cell bodies of motor neurons
• **posterior gray horn**
  - axons from sensory neurons
  - Cell bodies of interneurons
• **lateral gray horn**
  (T1-L2 only)
  - cell bodies of autonomic motor neurons
White matter

• Columns
  - segments of myelinated axons that lead up/down the spinal cord

• ascending tracts
  - lead up the spinal cord to the brain
  - Example: spinothalmic tract

• descending tracts
  - lead from the brain down to the spinal cord
  - Example: corticospinal tract
## Regional differences

<table>
<thead>
<tr>
<th>Region</th>
<th>Diameter</th>
<th>Shape</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>Largest (10-15 mm)</td>
<td>Oval with flattening</td>
<td>↑ white vs gray</td>
</tr>
<tr>
<td>Thoracic</td>
<td>Smaller</td>
<td>Oval with flattening</td>
<td>↑ white vs gray</td>
</tr>
<tr>
<td>Lumbar</td>
<td>&gt; thoracic</td>
<td>Almost circular</td>
<td>↓ white</td>
</tr>
<tr>
<td>Sacral</td>
<td>Smallest</td>
<td>Almost circular</td>
<td>White and gray equiv</td>
</tr>
</tbody>
</table>
Regional differences in cross sections of spinal cord
Nervous system development

- **Forebrain**
  - forms the telencephalon and diencephalon
  - the cerebrum and diencephalon form after birth

- **midbrain**: forms the midbrain
  - remains the midbrain

- **hindbrain**: forms the myelencephalon and metencephalon
  - the pons, cerebellum and medulla oblongata after birth
Neural tube folds to become the CNS
Future neural crest

Neural plate

Ectoderm

Notochord

Mesoderm

Endoderm

Neural crest

Neural folds

Ectoderm

Notochord

Mesoderm

Neural groove

Neural crest

Neural tube

Mesoderm

Ectoderm

Notochord

Endoderm

(b) Transverse sections
Abnormalities of neural tube development
Spina bifida
Spina bifida
Spina bifida: Myelomeningocele (open protrusion but no spinal cord elements outside)
Anencephaly
Failure of neural tube to close at top
Result: No forebrain or cerebrum
Baby never gains consciousness
Fatal
70% of these defects can be prevented by providing the mother with folic acid (vitamin B9) during the first few weeks of pregnancy.

2500 neonates are born each year in the US with neural tube defects (NTD).