CNS consists of brain and spinal cord

**Cephalization**

- Evolutionary development of rostral (anterior) portion of CNS
- Increased number of neurons in head
- Highest level reached in human brain
Mostly to orient view of embryonic disc

Ectoderm, mesoderm, endoderm - primitive tissues from which all body organs derive

*Epithelia* cells

Ectoderm $\rightarrow$ nervous system; skin
epidermis

Endoderm $\rightarrow$ epithelial linings of digestive, respiratory, urogenital systems; associated glands

*Mesenchyme* cells

Mesoderm $\rightarrow$ everything else
After primitive embryonic tissues developed = cells committed to pathways from those tissues
Ectodermal layer develops a groove and then an in-folding and then fuses into a tube
Brain and spinal cord begin as **neural tube**

3 primary vesicles form at anterior end
- **Prosencephalon** or forebrain
- **Mesencephalon** or midbrain
- **Rhomencephalon** or hindbrain

Posterior end becomes spinal cord
Primary vesicles → 5 secondary brain vesicles

- Forebrain → telencephalon and diencephalon
- Midbrain remains undivided
- Hindbrain → metencephalon and myelencephalon
Embryonic Development

Telencephalon → cerebral hemispheres
Diencephalon → epithalamus, thalamus, hypothalamus, and retina
Mesencephalon → midbrain
Metencephalon → pons and cerebellum
Myelencephalon → medulla oblongata
Central cavity of neural tube → ventricles
Central cavity of neural tube → ventricles
Brain grows faster than membranous skull

- Folds to occupy available space
- Forebrain moved toward brain stem (midbrain, pons, medulla oblongata)
- Cerebral hemispheres double back and envelop diencephalon and midbrain while creasing and folding to increase surface area
**Figure 12.2a** Brain development.

**Anterior (rostral)**
- Metencephalon
- Mesencephalon
- Diencephalon
- Telencephalon
- Myelencephalon

**Posterior (caudal)**
- Midbrain
- Cervical
- Spinal cord

**Flexures**

**(a) Week 5:** Two major flexures form, causing the telencephalon and diencephalon to angle toward the brain stem.
Figure 12.2b  Brain development.

(b) **Week 13:** Cerebral hemispheres develop and grow posterolaterally to enclose the diencephalon and the rostral brain stem.
Adult brain regions

1. Cerebral hemispheres
2. Diencephalon
3. Brain stem (midbrain, pons, and medulla)
4. Cerebellum
Spinal cord

- Central cavity surrounded by gray matter
- External white matter composed of myelinated fiber tracts
Meninges

Function of meninges:
- Cover and protect CNS
- Protect blood vessels and enclose venous sinuses
- Contain cerebrospinal fluid (CSF)
- Form partitions in skull

Consists of three layers (from external to internal): dura mater, arachnoid mater, and pia mater
Dura mater

Strongest meninx

Made up of two layers of fibrous connective tissue

*Periosteal layer* attaches to inner surface of skull

Found only in brain, not spinal cord

*Meningeal layer*: true external covering of brain

Extends into vertebral canal as spinal dura mater

Two layers are mostly fused, but separate in certain areas to form **dural venous sinuses**

Sinuses collect venous blood from brain, empty into jugular veins of neck
Dura mater extends inward in several areas to form flat partitions that divide cranial cavity

Partitions referred to as **dural septa**

Act to limit excessive movement of brain

Three main septa:

- **Falx cerebri**: in longitudinal fissure; attached to crista galli
- **Falx cerebelli**: along vermis of cerebellum
- **Tentorium cerebelli**: horizontal dural fold over cerebellum and in transverse fissure
**Arachnoid mater**

- Middle layer with spiderweb-like extensions
- Separated from dura mater by **subdural space**

**Subarachnoid space** contains CSF and largest blood vessels of brain

**Arachnoid granulations** protrude through dura mater into superior sagittal sinus

- Permit reabsorption of CSF back into venous blood
**Pia mater**

Delicate connective tissue that clings tightly to brain, following every convolution

Contains many tiny blood vessels that feed brain
Clinical – Homeostatic Imbalance 12.9

- *Meningitis*: inflammation of the meninges
- May spread to CNS, which would lead to inflammation of the brain, referred to as *encephalitis*
- Meningitis is usually diagnosed by observing microbes in a sample of CSF obtained via lumbar puncture
Brain (brainstem, anyway)

- Brainstem similar pattern to spinal cord
- Additional areas of gray matter in brain
Brainstem

Similar pattern

Additional areas of gray matter in brain
Additional areas of gray matter in brain
Cerebral hemispheres and cerebellum
Outer gray matter called cortex
Paired, C-shaped lateral ventricles in cerebral hemispheres

Separated anteriorly by **septum pellucidum**

Third ventricle in diencephalon

Fourth ventricle in hindbrain

Three openings: paired lateral apertures in side walls; median aperture in roof

Connect ventricles to subarachnoid space
Filled with cerebrospinal fluid (CSF)
Lined by ependymal cells
Connected to one another and to central canal of spinal cord
  Lateral ventricles $\rightarrow$ third ventricle via interventricular foramen
  Third ventricle $\rightarrow$ fourth ventricle via cerebral aqueduct
**Choroid plexus**: cluster of capillaries that hangs from roof of each ventricle, enclosed by pia mater and surrounding layer of ependymal cells

- CSF is filtered from plexus at constant rate
- Ependymal cells use ion pumps to control composition of CSF and help cleanse CSF by removing wastes
- Cilia of ependymal cells help to keep CSF in motion

Normal adult CSF volume of ~150 ml is replaced every 8 hours
Cerebrospinal fluid (CSF) forms a liquid cushion of constant volume around brain

Functions

- Gives buoyancy to CNS structures
  - Reduces weight of brain by 97% by floating it so it is not crushed under its own weight
- Protects CNS from blows and other trauma
- Nourishes brain and carries chemical signals

Composed of watery solution formed from blood plasma, but with less protein and different ion concentrations from plasma
Five lobes

- Frontal
- Parietal
- Temporal
- Occipital
- Insula
Insula
Surface markings

Ridges \textit{(gyri)}, shallow grooves \textit{(sulci)}, and deep grooves \textit{(fissures)}
Longitudinal fissure
Separates two hemispheres
Transverse cerebral fissure
Separates cerebrum and cerebellum
Central sulcus

Separates precentral gyrus of frontal lobe and postcentral gyrus of parietal lobe

Parieto-occipital sulcus

Separates occipital and parietal lobes

Lateral sulcus outlines temporal lobes
Three basic regions

- **Cerebral cortex** of gray matter superficially
- **White matter** internally
- **Basal nuclei** deep within white matter
Thin (2–4 mm) superficial layer of gray matter

40% mass of brain

Site of conscious mind: awareness, sensory perception, voluntary motor initiation, communication, memory storage, understanding
Has six layers:
I Molecular layer
II External granular layer
III External pyramidal layer
IV Internal granular layer
V Internal pyramidal layer
VI Multiform (polymorphic layer)
Has six layers:
I Molecular layer
II External granular layer
III External pyramidal layer
IV Internal granular layer
V Internal pyramidal layer
VI Multiform (polymorphic layer)
Layer 1 consists mainly of apical dendrites from pyramidal cells from lower layers — plus axons synapsing on those dendrites. It contains almost no neuron cell bodies.
Layer 2 contains many small densely-packed pyramidal neurons — giving it a granular appearance.
Layer 3 contains medium-sized pyramidal neurons which send outputs to other cortical areas.
Layer 4 contains many spiny stellate (excitatory) interneurons
Layer 5 contains the largest pyramidal neurons, which send outputs to the brain stem and spinal cord (the pyramidal tract)
Layer 6 consists of pyramidal neurons and neurons with spindle-shaped cell bodies.
“A Brodmann area is a region of the cerebral cortex, in the human or other primate brain, defined by its cytoarchitecture, or histological structure and organization of cells.” Wikipedia

52 original areas duplicated in hemispheres
Subsequently subdivided areas as more refined techniques developed.
Functional separation of parts of the cortex grossly matches cytoarchitectural differences
Cortical neurons interconnected in vertical columns
Presumably all cells functionally related – all have same precise (or very, very close) receptive fields
1. Three types of functional areas
   - Motor areas—control voluntary movement
   - Sensory areas—conscious awareness of sensation
   - Association areas—integrate diverse information
2. Each hemisphere concerned with contralateral side of body
3. Lateralization (specialization) of cortical function in hemispheres
4. Conscious behavior involves entire cortex in some way
**Broca's area** anterior to inferior premotor area

**Frontal eye field** within and anterior to premotor cortex; superior to Broca's area
In frontal lobe; control voluntary movement

*Primary (somatic) motor cortex in precentral gyrus*

*Premotor cortex* anterior to precentral gyrus
Allows conscious control of precise, skilled, skeletal muscle movements
Betz cells – very large pyramidal neurons in layer V of pre-central gyrus
Next slide
Large pyramidal cells of precentral gyri
Long axons → **pyramidal (corticospinal) tracts** of spinal cord
Motor homunculi - upside-down caricatures represent contralateral motor innervation of body regions
Premotor Cortex
Helps plan movements; staging area for skilled motor activities
Controls learned, repetitious, or patterned motor skills
Coordinates simultaneous or sequential actions
Controls voluntary actions that depend on sensory feedback
Broca's Area
Present in one hemisphere (usually the left)
Motor speech area that directs muscles of speech production
Active in planning speech and voluntary motor activities
Frontal Eye Field
Controls voluntary eye movements
Figure 12.6b Functional and structural areas of the cerebral cortex.

(b) Parasagittal view, right cerebral hemisphere

- Primary motor cortex
- Motor association cortex
- Primary sensory cortex
- Sensory association cortex
- Multimodal association cortex
Conscious awareness of sensation

Occur in parietal, insular, temporal, and occipital lobes
Primary somatosensory cortex
Visual areas
Auditory areas
Vestibular cortex
Olfactory cortex
Gustatory cortex
Visceral sensory area
In postcentral gyri of parietal lobe
Receives general sensory information from skin, and proprioceptors of skeletal muscle, joints, and tendons
Capable of spatial discrimination: identification of body region being stimulated
Somatosensory homunculus upside-down caricatures represent contralateral sensory input from body regions
Somatosensory association cortex
Posterior to primary somatosensory cortex
Integrates sensory input from primary somatosensory cortex for understanding of object
Determines size, texture, and relationship of parts of objects being felt
Primary visual (striate) cortex

- Extreme posterior tip of occipital lobe
- Most buried in calcarine sulcus of occipital lobe
- Receives visual information from retinas
Visual association area

Surrounds primary visual cortex
Uses past visual experiences to interpret visual stimuli (e.g., color, form, and movement)

E.g., ability to recognize faces

Complex processing involves entire posterior half of cerebral hemispheres

Ventral Stream – “what” stream Dorsal Stream – “where” stream
Primary auditory cortex

Superior margin of temporal lobes

Interprets information from inner ear as pitch, loudness, and location
Auditory association area

- Located posterior to primary auditory cortex
- Stores memories of sounds and permits perception of sound stimulus
Posterior part of insula and adjacent parietal cortex
Responsible for conscious awareness of balance (position of head in space)
Primary olfactory (smell) cortex

- Medial aspect of temporal lobes (in piriform lobes)
- Part of primitive rhinencephalon, along with olfactory bulbs and tracts
- Remainder of rhinencephalon in humans part of limbic system
- Region of conscious awareness of odors
In insula just deep to temporal lobe
Involved in perception of taste
Posterior to gustatory cortex
Conscious perception of visceral sensations, e.g., upset stomach or full bladder
Receive inputs from multiple sensory areas
Send outputs to multiple areas, including premotor cortex
Allows meaning to information received, store in memory, tying to previous experience, and deciding on actions
Sensations, thoughts, emotions become conscious – makes us who we are
Three broad parts:

Anterior association area (prefrontal cortex)

Posterior association area

[and next slide]
Limbic association area
Part of limbic system
Involves cingulate gyrus, parahippocampal gyrus, and hippocampus
Provides emotional impact that makes scene important and helps establish memories
Most complicated cortical region
Involved with intellect, cognition, recall, and personality
Contains working memory needed for abstract ideas, judgment, reasoning, persistence, and planning
Development depends on feedback from social environment
Large region in temporal, parietal, and occipital lobes
Plays role in recognizing patterns and faces and localizing us in space
Involved in understanding written and spoken language (Wernicke's area)
Hemispheres almost identical

**Lateralization** - division of labor between hemispheres

**Cerebral dominance** - hemisphere dominant for language (left hemisphere - 90% people)
Left hemisphere
  Controls language, math, and logic
Right hemisphere
  Visual-spatial skills, intuition, emotion, and artistic and musical skills
Hemispheres communicate almost instantaneously via fiber tracts and functional integration
Myelinated fibers and tracts
Communication between cerebral areas, and between cortex and lower CNS

**Association fibers** — horizontal; connect different parts of same hemisphere

**Commissural fibers** — horizontal; connect gray matter of two hemispheres

**Projection fibers** — vertical; connect hemispheres with lower brain or spinal cord
Figure 12.8b  White fiber tracts of the cerebral hemispheres.

(b) Parasagittal section and dissection

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Subcortical nuclei
   Caudate nucleus
   Putamen
   Globus pallidus

Caudate nucleus + putamen = striatum

Associated with subthalamic nuclei (diencephalon) and substantia nigra (midbrain)
Functions thought to be

- Influence muscle movements
- Role in cognition and emotion
- Regulate intensity of slow or stereotyped movements
- Filter out incorrect/inappropriate responses
- Inhibit antagonistic/unnecessary movements
Three paired structures

**Thalamus**
**Hypothalamus**
**Epithalamus**

Encloses third ventricle
80% of diencephalon
Superolateral walls of third ventricle
Bilateral nuclei connected by interthalamic adhesion (intermediate mass)
Contains several nuclei, named for location
Nuclei project and receive fibers from cerebral cortex
Gateway to cerebral cortex

Sorts, edits, and relays ascending input

- Impulses from hypothalamus for regulation of emotion and visceral function
- Impulses from cerebellum and basal nuclei to help direct motor cortices
- Impulses for memory or sensory integration

Mediates sensation, motor activities, cortical arousal, learning, and memory
Forms inferolateral walls of third ventricle
Contains many nuclei

Example: mammillary bodies
  Paired anterior nuclei
  Olfactory relay stations

Infundibulum—stalk that connects to pituitary gland
Controls autonomic nervous system (e.g., blood pressure, rate and force of heartbeat, digestive tract motility, pupil size)

Physical responses to emotions (limbic system)

- Perception of pleasure, fear, and rage, and in biological rhythms and drives
Regulates body temperature – sweating/shivering
Regulates hunger and satiety in response to nutrient blood levels or hormones
Regulates water balance and thirst
Regulates sleep-wake cycles

**Suprachiasmatic nucleus** (biological clock)

Controls endocrine system

- Controls secretions of anterior pituitary gland
- Produces posterior pituitary hormones
Epithalamus

Most dorsal portion of diencephalon; forms roof of third ventricle

Pineal gland (body)—extends from posterior border and secretes melatonin

Melatonin—helps regulate sleep-wake cycle