Human Anatomy

Brain and Cranial Nerves

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Brain and Cranial Nerves

- An adult brain weighs between 1.35 and 1.4 kilograms (kg) (around 3 pounds) and has a volume of about 1200 cubic centimeters (cc).
- Brain size is not directly correlated with intelligence.
- It is not the physical size of the brain that determines intelligence—it is the number of active synapses.
The Brain’s 4 Major Regions

- **Cerebrum**, the diencephalon, the brainstem, and the cerebellum.
- The cerebrum is divided into two halves, called the left and right cerebral hemispheres.
- Each hemisphere is subdivided into **five functional areas** called **lobes**.
- Outer surface of an adult brain exhibits folds called **gyri** (gyrus) and shallow depressions between those folds called **sulci** (sulcus).
- The brain is associated with **12 pairs of cranial nerves**.
The Brain’s 4 Major Regions

- **Prosencephalon (forebrain)**
  - Telencephalon: cerebrum
  - Diencephalon: epithalamus, thalamus, hypothalamus

- **Mesencephalon (midbrain)**
  - Mesencephalon: cerebral peduncles, colliculi

- **Rhombencephalon (hindbrain)**
  - Metencephalon: pons, cerebellum
  - Myelencephalon: medulla oblongata
(e) Birth
Organization of Brain Tissue

- **Gray matter:**
  - motor neuron and interneuron cell bodies, dendrites, axon terminals
  - unmyelinated axons.

- **White matter:**
  - composed primarily of myelinated axons.

- During brain development, an outer, superficial region of gray matter forms from migrating peripheral neurons.

- External sheets of gray matter, called the cortex, cover the surface of most of the adult brain (the cerebrum and the cerebellum).
Organization of Brain Tissue

- **White** matter lies **deep** to the **gray** matter of the cortex.

- **Within the masses of white matter:**
  - discrete **innermost clusters of gray matter** called **cerebral nuclei** (or basal nuclei).
  - are oval, spherical, or sometimes irregularly shaped clusters of **neuron cell bodies**.
Support and Protection of the Brain

- The brain is protected and isolated by multiple structures:
  - bony cranium
  - Meninges:
    - Protective connective tissue membranes
    - surround and partition portions of the brain.
  - Cerebrospinal fluid (CSF)
    - acts as a cushioning fluid.
  - Blood-brain barrier:
    - prevents entry of harmful materials from the bloodstream.
Cranial Meninges

- **Three** dense regular connective tissue layers:
  - separate the soft tissue of the brain from the bones of the cranium.
  - Enclose and protect blood vessels that supply the brain.
  - Contain and circulate cerebrospinal fluid.
  - Parts of the cranial meninges form some of the veins that drain blood from the brain.

- From superficial to deep, the cranial meninges are the *dura mater*, the *arachnoid*, and the *pia mater*. 
Dura Mater

- **Tough membrane composed of two fibrous layers.**
- **Strongest** of the meninges.
- Dura mater is composed of two layers.
  - periosteal layer, the more superficial layer, attaches to the periosteum of the cranial bones
  - meningeal layer lies deep to the periosteal layer
- The meningeal layer is usually fused to the periosteal layer
  - Exception: in specific areas where the two layers separate to form large, blood-filled spaces called dural venous sinuses.
Arachnoid

- Also called the arachnoid mater or the arachnoid membrane.
- Lies immediately internal to the dura mater.
- Partially composed of a delicate web of collagen and elastic fibers, termed the arachnoid trabeculae.
- Between the arachnoid and the overlying dura mater is the subdural space.
- Immediately deep to the arachnoid is the subarachnoid space.
Pia Mater

- The **innermost** of the cranial meninges.
- Thin layer of delicate connective tissue that tightly adheres to the brain and follows every contour of the brain surface.
Cranial Dural Septa

- The meningeal layer of the dura mater extends as flat partitions (septa) deep into the cranial cavity;
  - at four locations
  - called cranial dural septa.

- Membranous partitions separate specific parts of the brain and provide additional stabilization and support to the entire brain.
  - falx cerebri
  - tentorium cerebelli
  - falx cerebelli
  - diaphragma sellae
Brain Ventricles

- Cavities or expansions within the brain that are derived from the lumen (opening) of the embryonic neural tube.
- Continuous with one another as well as with the central canal of the spinal cord.
- Four ventricles in the brain.
  - Two lateral ventricles are in the cerebrum, separated by a thin medial partition called the septum pellucidum
  - Within the diencephalon is a smaller ventricle called the third ventricle
    - Each lateral ventricle communicates with the third ventricle through an opening called the interventricular foramen
- The fourth ventricle is located within the pons and cerebellum.
(a) Lateral view
Cerebrospinal Fluid

- A clear, colorless liquid that circulates in the ventricles and subarachnoid space.
- Bathes the exposed surfaces of the central nervous system and completely surrounds it.
- Performs several important functions.
  - buoyancy
  - protection
  - environmental stability
- Formed by the choroid plexus in each ventricle.
- Produced by secretion of a fluid from the ependymal cells that originate from the blood plasma.
- Is similar to blood plasma.
Blood-Brain Barrier

- Nervous tissue is protected from the general circulation by the blood-brain barrier.
- Strictly regulates what substances can enter the interstitial fluid of the brain.
- Prevents exposure of neurons in the brain to drugs, waste products in the blood, and variations in levels of normal substances (ions, hormones) that could adversely affect brain function.
Blood-Brain Barrier

- Tight junctions prevent materials from diffusing across the capillary wall.
- Astrocytes act as “gatekeepers” that permit materials to pass to the neurons after leaving the capillaries.
- Is markedly reduced or missing in three distinct locations in the CNS: the choroid plexus, hypothalamus, and pineal gland.
Cerebrum

- Account for 83% of brain mass
- Fissures – deep grooves – separate major regions of the brain
  - Transverse fissure – separates cerebrum and cerebellum
  - Longitudinal fissure – separates cerebral hemispheres
- Sulci – grooves on the surface of the cerebral hemispheres
- Gyri – twisted ridges between sulci
- Prominent gyri and sulci are similar in all people
Cerebrum

- Deeper sulci divide cerebrum into lobes
- Lobes are named for the skull bones overlying them
- Central sulcus separates frontal and parietal lobes
  - Bordered by two gyri
    - Precentral gyrus
    - Postcentral gyrus
- Parieto-occipital sulcus
  - Separates the occipital from the parietal lobe
- Lateral sulcus
  - Separates temporal lobe from parietal and frontal lobes
- Insula – deep within the lateral sulcus
Left cerebral hemisphere

Right cerebral hemisphere

- Frontal lobes
- Parietal lobes
- Occipital lobes

Gyrus
Sulcus
Precentral gyrus
Central sulcus
Postcentral gyrus
Longitudinal fissure
Cerebrum: functional areas

- Home of our conscious mind
- Enables us to:
  - Be aware of ourselves and our sensations
  - Initiate and control voluntary movements
  - Communicate, remember, and understand
Cerebral cortex

- Composed of gray matter
  - Neuronal cell bodies, dendrites, and short axons
- Folds in cortex – triples its size
- Approximately 40% of brain’s mass
- Brodmann areas – 52 structurally distinct areas
Functional areas of the cortex

Three kinds of functional areas

- Motor areas
- Sensory areas
- Association areas
Motor areas

- Controls motor functions
  - Primary motor cortex (somatic motor area)
  - Located in precentral gyrus (Brodmann area 4)
- Pyramidal cells – large neurons of primary motor cortex
Motor areas

- Corticospinal tracts descend through brainstem and spinal cord
  - Axons signal motor neurons to control skilled movements
  - **Contralateral** — pyramidal axons cross over to opposite side of the brain
Motor areas

- Specific pyramidal cells control specific areas of the body
- Face and hand muscles – controlled by many pyramidal cells
- Motor homunculus – body map of the motor cortex
Sensory cortex

- Cortical areas involved in conscious awareness of sensation
- Located in parietal, temporal, and occipital lobes
- Distinct area for each of the major senses
Primary Somatosensory Cortex

- Located along the postcentral gyrus
  - Corresponds to Brodmann areas 1-3
- Involved with conscious awareness of general somatic senses
- Spatial discrimination – precisely locates a stimulus
Primary Somatosensory Cortex

- Projection is *contralateral*
  - Cerebral hemispheres
    - Receive sensory input from the opposite side of the body
- Sensory homunculus – a body map of the sensory cortex
Somatosensory Association Area

- Lies posterior to the primary somatosensory cortex
  - Corresponds to Brodmann areas 5 and 7
- Integrates different sensory inputs
  - Touch, pressure, and others
- Draws upon stored memories of past sensory experiences
Sensory Areas – Visual Areas

- Primary visual cortex
  - Corresponds to Brodmann area 17
  - Located deep within the calcarine sulcus
    - On the posterior and medial part of the occipital lobe
  - Receives visual information that originates on the retina
  - First of a series of areas that interprets visual input
Sensory Areas – Visual Areas

- Visual association area
  - Surrounds the primary visual area
  - Coincides with Brodmann areas 18 and 19
  - Continues the processing of visual information
- Complex visual processing extends into:
  - Temporal and parietal lobes
Primary auditory cortex
- Function – conscious awareness of sound
- Location – superior edge of the temporal lobe
- Corresponds to Brodmann areas 41 and 42
Auditory association area

- Lies posterior to the primary auditory cortex
- Located within Brodmann area 22
- Permits evaluation of different sounds
- Lies in the center of Wernicke’s area
- Involved in recognizing and understanding speech
Sensory Areas – Gustatory Cortex

- Involved in the conscious awareness of taste stimuli
- Corresponds to Brodmann area 43
- Located on the “roof” of the lateral sulcus
Sensory Areas – Vestibular Cortex

- Located in the posterior part of the insula
- Deep to the lateral sulcus
Sensory Areas – Olfactory Cortex

- Lies on the medial aspect of the cerebrum
- Located in a region called the **piriform lobe**
- Olfactory nerves transmit impulses to the olfactory cortex
  - Provides conscious awareness of smells
**Sensory Areas – Olfactory Cortex**

- Part of the rhinencephalon – “nose brain”
- Includes – the piriform lobe, olfactory tract, and olfactory bulb
- Connects the brain to the limbic system
  - Explains why smells trigger emotions
- Orbitofrontal cortex
  - Involved with consciously identifying and recalling specific smells
Association areas

- Make associations between different types of sensory information
- Associate new sensory input with memories of past experiences
- New name for association areas – higher order processing areas
Association Areas – Prefrontal Cortex

- Large region of the frontal lobe anterior to motor areas
- Performs cognitive functions
  - All aspects of thinking and perceiving
  - Remembering and recalling information
  - Also related to mood
  - Has close links to the limbic part of the forebrain
Association Areas – Prefrontal Cortex

- Functional neuroimaging techniques
  - Reveal functions of specific parts of the prefrontal cortex
- Anterior pole of frontal cortex
  - Active in solving the most complex problems
- The farther rostrally one goes in the CNS, the more complex the neural functions
Association Areas – Prefrontal Cortex

- Functional areas located on the medial side of the frontal lobe
  - Regions anterior to the corpus callosum
    - Involved in complex personal and social interactions
  - Regions superior to the corpus callosum
    - Involved in “mentalization”
Association Areas – General Interpretation Area

- Function is currently under investigation
- Located at the interface of:
  - The visual, auditory, and somatosensory association areas
- Newer studies show most of this region is involved in the visual processing of spatial relationships
Association Areas – Language Area

- Surrounds the lateral sulcus in the left cerebral hemisphere
- Five parts have been identified
  - Broca’s area – speech production
  - Wernicke’s area – speech comprehension
  - Lateral prefrontal cortex – conceptual analysis of spoken words
Association Areas – Language Area

- Five parts have been identified (continued)
  - Most of the lateral and inferior temporal lobe
    - Coordination of auditory and visual aspects of language
  - Parts of the insula
    - Initiation of word articulation
    - Recognition of rhymes and sound sequences
Association Areas – Insula

- Functions of its cortex – not well understood
- Some parts function in language and the sense of balance
- Other parts – visceral function
  - Conscious perception of:
    - Upset stomach
    - Full bladder
    - Some aspects of the sense of smell
Lateralization of Cortical Functioning

- The two hemispheres control opposite sides of the body
- Hemispheres are specialized for different cognitive functions
Lateralization of Cortical Functioning

- Left cerebral hemisphere – more control over:
  - Language abilities, math, and logic
- Right cerebral hemisphere – more involved with:
  - Visual-spatial skills
  - Reading facial expressions
  - Intuition, emotion, artistic and musical skills
Cerebral White Matter

- Different areas of the cerebral cortex communicate:
  - With each other
  - With the brainstem and spinal cord
- Fibers are usually myelinated and bundled into tracts
Cerebral White Matter

- Types of tracts
  - Commissures – composed of commissural fibers
    - Allows communication between cerebral hemispheres
    - Corpus callosum – the largest commissure
  - Association fibers
    - Connect different parts of the same hemisphere
Corpus callosum

Association tracts

Parietal lobe

Frontal lobe

Occipital lobe

Temporal lobe

(a) Sagittal view

Legend:
- Purple: Association tracts
- Blue: Commissural tracts
- Green: Projection tracts
Cerebral White Matter

- Types of tracts (continued)
  - Projection fibers – run vertically
    - Descend from the cerebral cortex
    - Ascend to the cortex from lower regions
Projection tracts

- **Internal capsule** – projection fibers form a compact bundle
  - Passes between the thalamus and basal nuclei

- **Corona radiata** – superior to the internal capsule
  - Fibers run to and from the cerebral cortex
Basal nuclei

- A group of nuclei deep within the cerebral white matter
  - Caudate nucleus – arches over the thalamus
  - Lentiform nucleus – “lens shaped”
  - Amygdala – sits on top of the caudate nucleus
    - Functionally belongs with the limbic system
Basal nuclei

- Lentiform nucleus
  - Divided into two parts
    - Globus pallidus
    - Putamen
Basal nuclei

- Cooperate with the cerebral cortex in controlling movements
- Receive input from many cortical areas
- Evidence shows that they:
  - Start, stop, and regulate intensity of voluntary movements
  - In some way estimate the passage of time
The Diencephalon

- Forms the center core of the forebrain
- Surrounded by the cerebral hemispheres
- Composed of three paired structures: Thalamus, hypothalamus, and epithalamus
- Border the third ventricle
- Primarily composed of gray matter
The Thalamus

- Makes up 80% of the diencephalon
- Contains approximately a dozen major nuclei
- Send axons to regions of the cerebral cortex
- Nuclei act as relay stations for incoming sensory messages
The Thalamus

- Afferent impulses converge on the thalamus
  - Synapse in at least one of its nuclei
- Is the “gateway” to the cerebral cortex
- Nuclei organize and amplify or tone down signals
The Diencephalon – The Hypothalamus

- Lies between the optic chiasm and the mammillary bodies
- Pituitary gland projects inferiorly
- Contains approximately a dozen nuclei
- Main visceral control center of the body
The Hypothalamus

Functions include the following:

- Control of the autonomic nervous system
- Control of emotional responses
- Regulation of body temperature
- Regulation of hunger and thirst sensations
- Control of behavior
- Regulation of sleep-wake cycles
- Control of the endocrine system
- Formation of memory
The Diencephalon – The Epithalamus

- Forms part of the “roof” of the third ventricle
- Consists of a tiny group of nuclei
- Includes the **pineal gland (pineal body)**
  - Secretes the hormone melatonin
  - Under influence of the hypothalamus
The Brain Stem

- Includes the midbrain, pons, and medulla oblongata
- Several general functions
  - Produces automatic behaviors necessary for survival
  - Passageway for all fiber tracts running between the cerebrum and spinal cord
  - Heavily involved with the innervation of the face and head
    - 10 of the 12 pairs of cranial nerves attach to it
The Brain Stem – The Midbrain

- Lies between the diencephalon and the pons
- Central cavity – the cerebral aqueduct
- Cerebral peduncles located on the ventral surface of the brain
  - Contain pyramidal (corticospinal) tracts
- Superior cerebellar peduncles
  - Connect midbrain to the cerebellum
The Brain Stem – The Midbrain

- Periaqueductal gray matter surrounds the cerebral aqueduct
  - Involved in two related functions
    - Fright-and-flight reaction
    - Mediates response to visceral pain
Cross-sectional view of mesencephalon

- Superior colliculus
- Mesencephalic aqueduct
- Reticular formation
- Periaqueductal gray matter
- Nucleus for oculomotor nerve
- Medial lemniscus
- Red nucleus
- Substantia nigra
- Cerebral peduncle
- Oculomotor nerve (CN III)
The Brain Stem – The Midbrain

- Corpora quadrigemina – the largest nuclei
  - Divided into the superior and inferior colliculi
    - Superior colliculi – nuclei that act in visual reflexes
    - Inferior colliculi – nuclei that act in reflexive response to sound
The Brain Stem – The Midbrain

- Imbedded in the white matter of the midbrain
  - Two pigmented nuclei
  - Substantia nigra – neuronal cell bodies contain melanin
    - Functionally linked to the basal nuclei
  - Red nucleus – lies deep to the substantia nigra
    - Largest nucleus of the reticular formation
Cross-sectional view of mesencephalon

- Superior colliculus
- Mesencephalic aqueduct
- Reticular formation
- Periaqueductal gray matter
- Nucleus for oculomotor nerve
- Medial lemniscus
- Red nucleus
- Substantia nigra
- Cerebral peduncle
- Oculomotor nerve (CN III)

Anterior

Posterior
The Brain Stem – The Pons

- Located between the midbrain and medulla oblongata
- Contains the nuclei of cranial nerves V, VI, and VII
- Two general groups of cranial nerve nuclei
  - Motor nuclei
  - Sensory nuclei
(b) Pons cross section
The Brain Stem – The Medulla Oblongata

- Most caudal level of the brain stem
  - Continuous with the spinal cord
  - **Choroid plexus** lies in the roof of the fourth ventricle
  - Pyramids of the medulla – lie on its ventral surface
    - Decussation of the pyramids – crossing over of motor tracts
  - Cranial nerves VIII–XII attach to the medulla
The Brain Stem – The Medulla Oblongata

- The core of the medulla contains:
  - Much of the reticular formation
    - Nuclei influence autonomic functions
  - Visceral centers of the reticular formation include:
    - Cardiac center
    - Vasomotor center
    - The medullary respiratory center
    - Centers for hiccupping, sneezing, swallowing, and coughing
(a) Medulla oblongata, cross-sectional view
(b) Medulla oblongata, lateral view
The Cerebellum

- Located dorsal to the pons and medulla
  - Smoothes and coordinates body movements
  - Helps maintain equilibrium
The Cerebellum

- Consists of two cerebellar hemispheres
- Surface folded into ridges called **follia**
  - Separated by fissures
- Hemispheres each subdivided into:
  - Anterior lobe
  - Posterior lobe
(b) Cerebellum, superior view
The Cerebellum

- Composed of three regions
  - Cortex – gray matter
  - Internal white matter
  - Deep cerebellar nuclei – deeply situated gray matter

- Cerebellum must receive information
  - On equilibrium
  - On current movements of limbs, neck, and trunk
  - From the cerebral cortex
The Cerebellum – Cerebellar Peduncles

- Fibers to and from the cerebellum are \textit{ipsilateral}
  - Run to and from the \textit{same} side of the body
- Thick tracts connecting the cerebellum to the brain stem
  - Superior cerebellar peduncles
  - Middle cerebellar peduncles
  - Inferior cerebellar peduncles
Functional Brain Systems

- Networks of neurons functioning together
  - The limbic system – spread widely in the forebrain
  - The reticular formation – spans the brain stem
Functional Brain Systems – The Limbic System

- **Location**
  - Medial aspect of cerebral hemispheres
  - Also within the diencephalon

- **Composed of:**
  - Septal nuclei, cingulate gyrus, and hippocampal formation
  - Part of the amygdala

- The fornix and other tracts link the limbic system together
Functional Brain Systems – The Limbic System

- The “emotional brain”
  - Cingulate gyrus
    - Allows us to shift between thoughts
    - Interprets pain as unpleasant
- Hippocampal formation
  - Hippocampus and the parahippocampal gyrus
Functional Brain Systems – The Reticular Formation

- Runs through the central core of the medulla, pons, and midbrain
- Forms three columns
  - Midline raphe nuclei
  - Medial nuclear group
  - Lateral nuclear group
Functional Brain Systems – The Reticular Formation
Functional Brain Systems – The Reticular Formation

- Widespread connections
  - Ideal for arousal of the brain as a whole
- Reticular activating system (RAS)
  - Maintains consciousness and alertness
  - Functions in sleep and arousal from sleep
Functional Brain Systems – The Reticular Formation