Central Nervous System

• CNS – composed of the brain and spinal cord

• Cephalization
  – Refers to Evolutionary Elaboration of the anterior portion of the CNS
  – End result is an Increase in number of neurons in the head
  – Highest level is reached in the human brain
Central Nervous System

- During the first 26 days of development:
  - Ectoderm on the developing embryo thickens, forming the neural plate
  - The neural plate invaginates, forming the neural groove
  - The neural groove fuses dorsally and forms the neural tube

Central Nervous System

At the end of the 4th week, the anterior end of the neural tube expands and constricts to form the three primary brain vesicles:

- Prosencephalon: the forebrain
- Mesencephalon: the midbrain
- Rhombencephalon: the hindbrain
At the end of the 6th week, 3 primary brain vesicles develop into the secondary brain vesicles, which will form the future adult brain structures.

- **Telencephalon** and **diencephalon** arise from the forebrain
- **Mesencephalon** remains undivided
- **Metencephalon** and **myelencephalon** arise from the hindbrain

### Central Nervous System

#### Fates of the secondary brain vesicles

<table>
<thead>
<tr>
<th>(c) Secondary brain vesicles</th>
<th>(d) Adult brain structures</th>
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<tbody>
<tr>
<td>Telencephalon</td>
<td>Cerebrum: cerebral hemispheres (cortex, white matter, basal nuclei)</td>
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<tr>
<td>Diencephalon</td>
<td>Diencephalon (thalamus, hypothalamus, epithalamus), retina</td>
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<tr>
<td>Mesencephalon</td>
<td>Brain stem: midbrain</td>
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<tr>
<td>Metencephalon</td>
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<tr>
<td>Myelencephalon</td>
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<td></td>
<td>Brain stem: medulla oblongata</td>
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<td>Spinal cord</td>
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**Adult Brain Areas**

- Six regions in the adult brain
  - Cerebrum
  - Diencephalon
  - Mesencephalon (midbrain)
  - Pons
  - Medulla oblongata
  - Cerebellum

**Primary brain vesicles**

- Diagram showing various brain vesicles with labels such as Lamina terminalis, Telencephalon, Diencephalon, Mesencephalon, Myelencephalon, Spinal cord, Optic vesicle, Telenencephalon.
### Basic Pattern of CNS

- **Spinal Cord**
  - Central cavity surrounded by a gray matter core
  - External to which is white matter composed of myelinated fiber tracts

- **Brain**
  - Similar to spinal cord but with additional areas of gray matter
  - Cerebellum has gray matter in nuclei
  - Cerebrum has nuclei and additional gray matter in the cortex
Ventricles of the Brain

- Central passageway of the brain enlarges to form the ventricles. They contain cerebrospinal fluid (CSF) and are continuous with the central canal of the spinal cord.
- They arise from expansion of the lumen of the neural tube.
- The ventricles are:
  - The paired C-shaped lateral ventricles
  - The third ventricle found in the diencephalon
  - The fourth ventricle found in the hindbrain dorsal to the pons.

Adult structures derived from the neural canal
Ventricles of the Brain

- Form the protective membranes of the brain
- Located immediately deep to the skull
  - Dura mater
  - Arachnoid mater
  - Pia mater

The cranial meninges
Cerebrospinal fluid (CSF)

- CSF cushions delicate neural structures
- Supports the brain
- Transports nutrients, chemical messengers, and waste products
- CSF is produced in the Choroid plexuses of the ventricles
  - Travels through the lateral and medial apertures to the subarachnoid space and central canal of spinal cord

Choroid Plexuses

CSF is produced mainly by structures called the choroid plexus in the lateral, third and fourth ventricles.

The choroid plexuses are networks of ventricular capillaries covered by ependymal cells. They form CSF by filtration of blood plasma and then secreting it into the ventricles.
The Circulation of CSF

Cerebrospinal Fluid flows through all ventricles, from lateral towards 4th ventricle

It then flows into the central canal of the spinal cord and up the brain in the sub-arachnoid spaces

It is re-directed to the bloodstream via arachnoid villi into the superior sagittal sinus (a venous blood vessel).

Total CSF = ~ 150 ml

We make about 480 ml each day

That is why it needs to be recirculated back to the bloodstream or we end up with too much CSF, which may result in excessive pressure in the CNS!
Re-absorption of CSF occurs at the **Arachnoid Villi**, which protrude from arachnoid matter, through dura matter and into the blood vascular sinus.

Blood vascular sinus is located between folds of the dura mater (endosteal layer and meningeal layer).

Blockage of the **Arachnoid Villi** in babies results in a condition called **HydroCephalus**. The CFS remains in the subarachnoid space and causes outwards pressure on the flexible skull.
The Cerebral Hemispheres

- The Cerebral Hemispheres form the superior part of the brain and make up 83% of its mass
- Contain ridges (gyri) and shallow grooves (sulci)
- Contain deep grooves called fissures
- Are separated by the longitudinal fissure
- The Cerebral Hemispheres have three basic regions: cortex, white matter, and basal nuclei
Deep sulci divide the hemispheres into five lobes:
- Frontal
- Parietal
- Temporal
- Occipital
- Insula

The **Central sulcus** separates the frontal and parietal lobes.

The precentral and postcentral gyri border the central sulcus.
The Cerebral Cortex

The cerebral cortex is the executive suite of the nervous system

The cortex refers to the **upper outer layer** of the cerebrum and contains mostly neuron cell bodies, dendrites and unmyelinated axons (the gray matter).

This cortex gray matter governs all aspects and qualities of our conscious behavior.

Although function can sometimes be correlated with certain brain areas, other functions are more difficult to locate and seem to be complex and overlapping.
The cortex is the superficial gray matter; it accounts for 40% of the mass of the brain.

The cerebral cortex enables sensation, communication, memory, understanding, and voluntary movements.

1. No functional area of the cortex acts alone; conscious behavior involves the entire cortex
2. There are 3 kinds of functional areas:
   • Motor areas: control voluntary motor functions
   • Sensory areas: provide for conscious awareness and sensation
   • Association areas: act to integrate the diverse information
3. Each hemisphere is concerned with the sensory and motor function of the opposite side
4. The two hemisphere are not entirely equal in function (lateralization, specialization)

The gray cortex area of the cerebrum has several areas with very specific functions. These functional areas can be categorized in the following ways:

• Motor areas
• Sensory areas
• Association areas
Cerebral Cortex: Motor Areas

All Motor Areas are located in front of the central sulcus; thus they are all in the frontal lobe.

- Primary (somatic) motor cortex
- Premotor cortex
- Broca’s area
- Frontal eye field

Primary Motor Area

- Located in the precentral gyrus
- Each muscle in the body is controlled by a specific region in this brain area
- The body can be “mapped” on this precentral gyrus according to what muscle is being moved.
- The resulting motor body is called the motor homunculus.
- Lesions or damage in a specific area will thus result in complete loss of a specific muscle function of that body area.
The “Motor Homunculus” is thus an imaginary cartoon-man drawn over the precentral gyrus, according to which gyrus-area is responsible for certain muscles. This diagram shows a frontal section through the precentral gyrus.

The more brain area devoted to areas of muscles, the larger that part of the cartoon man.

**Primary Motor Area**

Damage to this area in the precentral gyrus will result in loss of the use of tongue motion.

**Pre Motor Cortex Area**

- Located anterior to the precentral gyrus
- Controls learned, repetitious, or patterned motor skills
- Coordinates simultaneous or sequential actions
- Involved in the planning of movements

Thus damage to the precentral gyrus will result in loss of the ability to move a specific muscle. Damage to the premotor area results in loss of planned motions.
Pre Motor Cortex Area

Broca’s Area and Frontal Eye Field

- Broca’s area
  - Located anterior to the inferior region of the premotor area
  - Present in one hemisphere (usually the left)
  - A motor speech area that directs muscles of the tongue
  - Is active as one prepares to speak

- Frontal eye field
  - Located anterior to the premotor cortex and superior to Broca’s area
  - Controls voluntary eye movement
The sensory areas are brain cortex areas concerned with conscious awareness of sensation and occur in the regions behind the central sulcus.

- **Primary (Somato)Sensory Cortex**
- **Primary Visual Cortex**
- **Primary Auditory Cortex**
- **Primary Gustatory Cortex**
- **Primary Olfactory Cortex**

In addition, these primary areas have association areas in close proximity.
Primary (Somato) Sensory Area

- Resides in the postcentral gyrus of the parietal lobe, behind the central sulcus.
- Neurons here receive information from sensory receptors (pain, temperature, touch) located in the skin and from proprioreceptors (joints, muscle position) in skeletal muscle.
- It allows for spatial discrimination and identification of the body region being stimulated.
The display and mapping of the body areas that direct information to specific areas within the primary somatosensory cortex is called the somatosensory homunculus.

The amount of sensory cortex devoted to a particular body region is related to how sensitive the region is, not the size of the body region. (Face, lips, fingertips are most sensitive.)

The shape of the sensory homunculus of different mammals reflects the way the mammals feels and interacts with the environment.
- Located posterior to the primary somatosensory cortex
- Integrates sensory information
- Forms comprehensive understanding of the stimulus
- Determines size, texture, and relationship of parts
Visual Cortex Areas

• Primary visual (striate) cortex
  – Seen on the extreme posterior tip of the occipital lobe
  – Most of it is buried in the calcarine sulcus
  – Receives visual information from the retinas

• Visual association area
  – Surrounds the primary visual cortex
  – Interprets visual stimuli (e.g., color, form, and movement)

Auditory Cortex Areas

• Primary auditory cortex
  – Located at the superior margin of the temporal lobe
  – Receives information related to pitch, rhythm, and loudness

• Auditory association area
  – Located posterior to the primary auditory cortex
  – Stores memories of sounds and permits perception of sounds
  – Wernicke’s area
Comparing cerebral cortex areas can provide insights as to what senses are important in other animals.

In this case, what senses are important in rats and tarsiers?

And what is a tarsier?
The tarsier of Southeast Asia has the largest eyes relative to body size of any living creature. The eyes are so enormous that they cannot be moved in their sockets. To compensate, tarsiers can swivel their necks 180 degrees in either direction. Though most nocturnal primates eat insects, the tarsier likes meat and has the vision, speed and reflexes to catch small prey in pitch darkness.

**Cerebral Cortex Areas**

**Other important Association Areas**

**Prefrontal Cortex**

- located in the anterior area of the frontal lobe
- coordinates information relayed from all the other association areas
  - Involved with intellect, cognition, recall, and personality
  - Necessary for judgment, reasoning, persistence, and conscience
  - aspects of learning consequences from actions, social responses, ethical views, frustrations, tensions, anxiety are related to this area.

Prefrontal lobotomies, cutting or scraping away most of the connections to and from the prefrontal cortex, were used in the 1950’s and 60’s to treat schizophrenia, clinical depression, various anxiety disorders and even ADD in children.
**Association Area: pre-frontal cortex**

**The case of Phineas Gage**

On September 13, 1848, he endured a catastrophic construction accident during which a 13-pound iron rod pierced through his cheek and exited from the top of his skull, resulting in severe injury to his left prefrontal cortex. To everyone's dismay, Phineas Gage lived.

But... he no longer could filter his thoughts, behaviors or social interactions. Being a mild manner person before, he showed dramatic personality changes including being "fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows,..."

These findings have resulted in "crucial role in the discovery of behavioral syndromes resulting from frontal lobe dysfunction."

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**Integration Areas**

**Gnostic area or General Interpretation area**

- Region that encompasses parts of the temporal, parietal, and occipital lobes. Located posterior to the auditory association area and usually equated with Wernicke's area.
- Only found in one hemisphere but not the other; most often the left hemisphere.
- Receives information from all sensory association areas...This area integrates sensory information (especially, visual and auditory) into a comprehensive understanding, then sends the assessment to the prefrontal cortex, which adds an emotional element before deciding on a response.
- A person with global damage to this area usually suffer from fluent aphasia (failure to understand spoken language).
The interior of the brain is mostly white matter; these are myelinated axons that provide the “wiring”.

White matter can be classified into 3 major categories:

- Association fibers
- Commissural fibers
- Projection fibers

Association fibers:
these areas of the brain within a single hemisphere. Smaller ones are called arcuate fibers, longer one are referred to as fasciculi

Commissural fibers:
interconnect the two hemispheres. Examples are the Corpus callosum and the anterior commissure

Projection fibers:
link the cerebral cortex to thalamus, brain stem, spinal cord (they project downwards and upwards)
**Inner Gray Matter**

- The cortex of the cerebrum contains the gray matter. These are the cell bodies, dendrites and unmyelinated axons. This is where most of our conscious activities occur.
- Deep inside the brain are areas of gray matter that process information outside our conscious awareness.
- Such pockets of gray matter are often referred to as Nuclei (do not confuse with nucleus of a cell).
- Basal nuclei are such areas of gray matter, located deep to the floor of the lateral ventricles

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**The Basal Nuclei**

The main mass of these nuclei is formed by two nuclei collectively referred to as the corpus striatum.

It consists of:
- caudate nucleus
- lentiform nucleus

The lentiform nucleus itself is made up of a lateral part (the putamen) and a medial part (the globus pallidus)
The Basal Nuclei

The basal nuclei receive extensive inputs from the entire cerebral cortex.

Via relays through the thalamus, it projects to the premotor and prefrontal areas and thus influences muscle motor movements directed by the primary motor cortex.

It does not activate muscle movements directly

- involved in subconscious control of muscle tone
- monitors and coordinates learned movement patterns
- provides general patterns of rhythm of motion in progress
- inhibits antagonistic movements
The Basal Nuclei

Parkinson’s Disorder

Under normal circumstances, Substantia nigra neurons (located in the midbrain) inhibit the activity of the basal ganglia by releasing dopamine.

Damage to the Substantia niagra and a loss of dopamine receptors in basal ganglia results in increased activity of the basal ganglia.

Recent evidence indicate that environmental pesticides may be involved.