OVERVIEW OF THE NERVOUS SYSTEM

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Lecture Outline:

I. Nervous System Purpose
II. Nervous System Divisions
III. Major Divisions of the Brain
IV. Anatomical Organization of the Nervous System
V. Cerebrum
VI. Brainstem
VII. Cerebellum
VIII. Spinal Cord
IX. CNS Protection and Support
    A. Meninges and CSF
    B. Blood Supply
    C. Blood-Brain Barrier
X. Terms and Definitions Familiar to the Nervous System

Objectives:

1. Describe the role of the nervous system.
2. Describe the characteristics of the Peripheral Nervous System vs. the Central Nervous System.
3. Describe the major components of the CNS and where they are located.
4. Differentiate gray vs. white matter as well as anatomical organization of the nervous system.
5. Describe the location of the 4 lobes of the cerebral hemispheres.
6. Describe the regions of the brain stem.
7. Describe the location and general functions of the cerebellum.
8. Describe the organization of the spinal cord.
9. Describe the properties of the meninges and CSF.
10. Explain arterial blood input and venous blood output for the brain.
11. Explain the function and composition of the blood brain barrier.
12. Understand the terms and directions and relationships between structures in the nervous system.

Slide 1

Nervous System Overview

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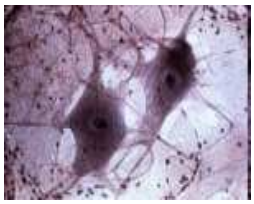
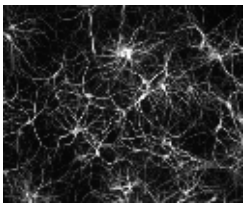
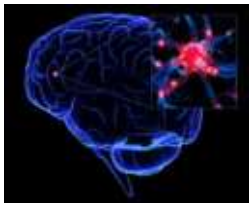
Slide 2

Purpose of the Nervous System

- Communication
  - Receive information from outside
  - Integrate with internal information
  - Produce responses - movement & behavior
- Neurons - cells specialized for communication
  - speed
  - Specificity
  - distance

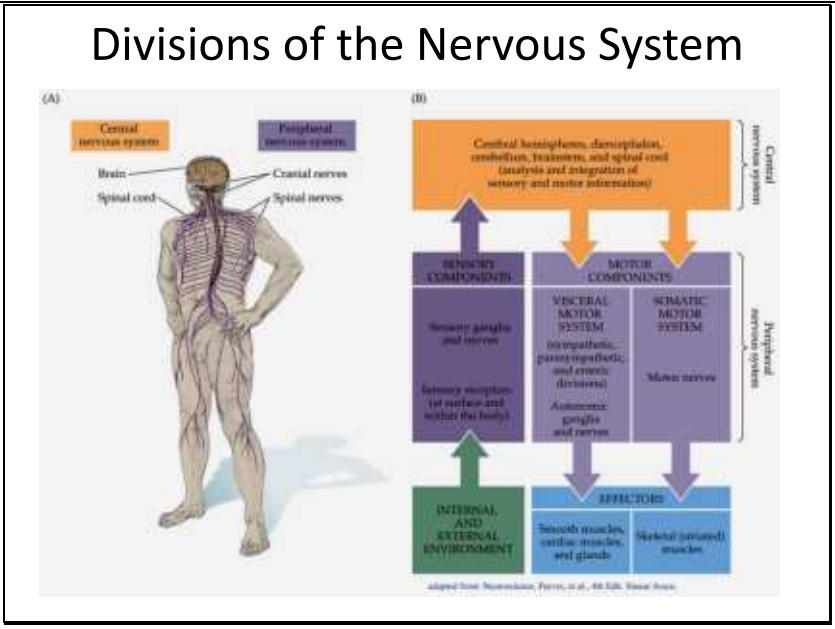
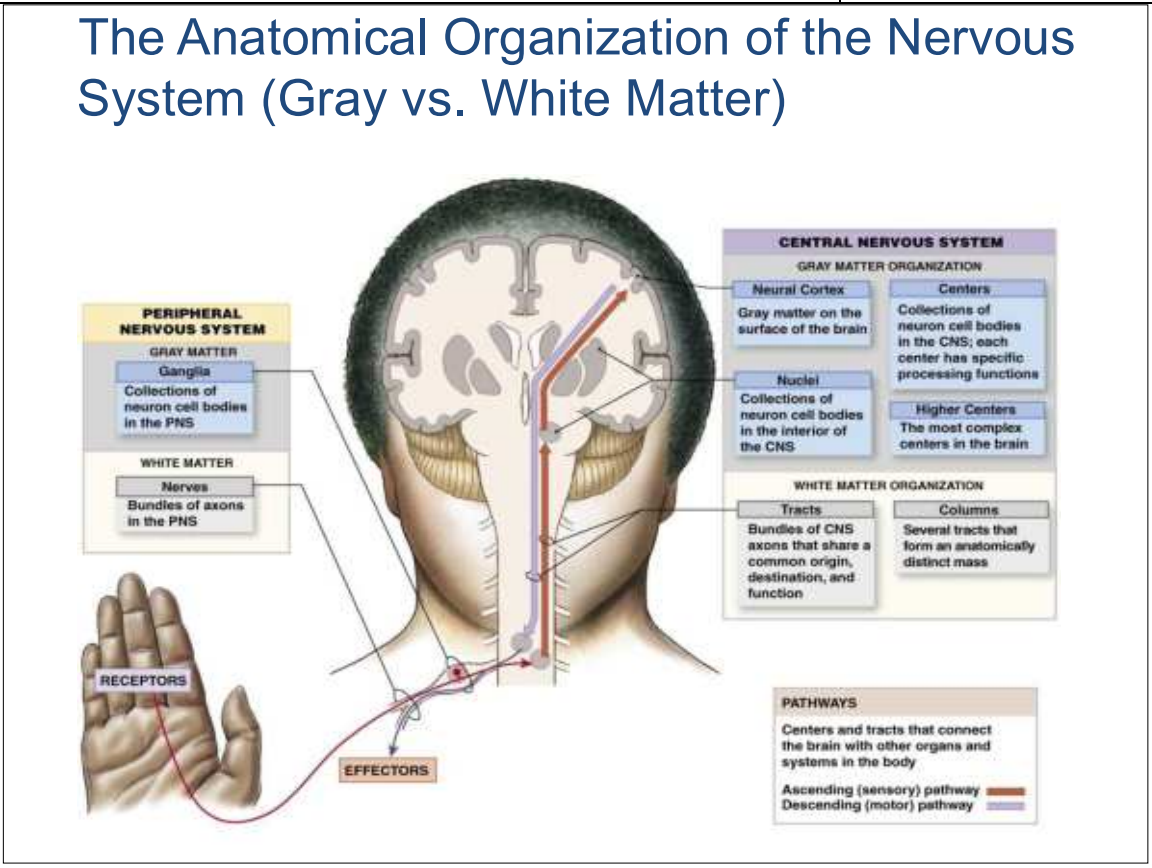






The function of the nervous system is to process information through neuron-to-neuron communication. There are three components of this processing: (1) to receive and interpret all outside stimuli, (2) to integrate information from the outside world with internal information, and (3) to initiate appropriate responses to the environment, especially movement and behavior.

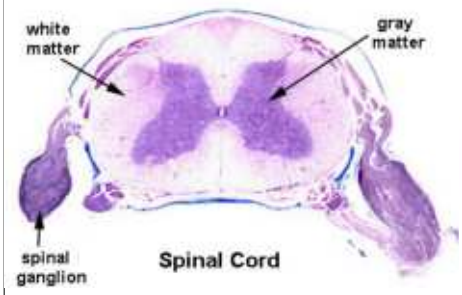
Neuron-to-neuron communication, as opposed to hormonal, is the principal means for communication because of: speed (nerve conduction occurs in microseconds and synaptic transmission occurs in milliseconds; specificity (neurons are *spatially* selective about where they synapse and *temporally* specific about when they fire); and distance (axons can carry messages over tens of centimeters).

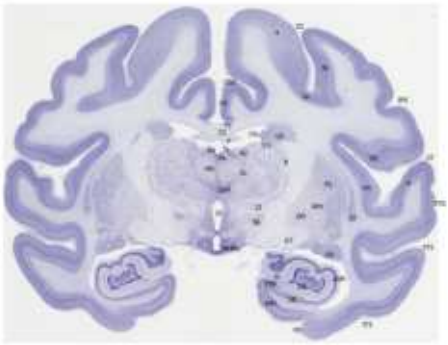
Slide 3		The nervous system is made up of: Central nervous system (brain and spinal cord) Peripheral nervous system (spinal nerves and cranial nerves)
Slide 4	 The nervous system is well organized in that it contains gray matter (mostly neuronal cell bodies) and white matter (mostly axons). In the CNS gray matter is located on the 1) surface of the brain, 2) in subcortical regions called nuclei, 3) and the most central region of the spinal cord. White matter in the CNS exists as tracts (within the brain and spinal cord) and columns (exterior region of the spinal cord). The gray matter of the PNS is often referred to as ganglia, again containing neuronal cell bodies, and the white matter is often referred to as nerves (bundle of axons).	

Slide 5

Brain vs Spinal Cord Organization

- Cresyl Violet (Nissl) emphasizing gray matter



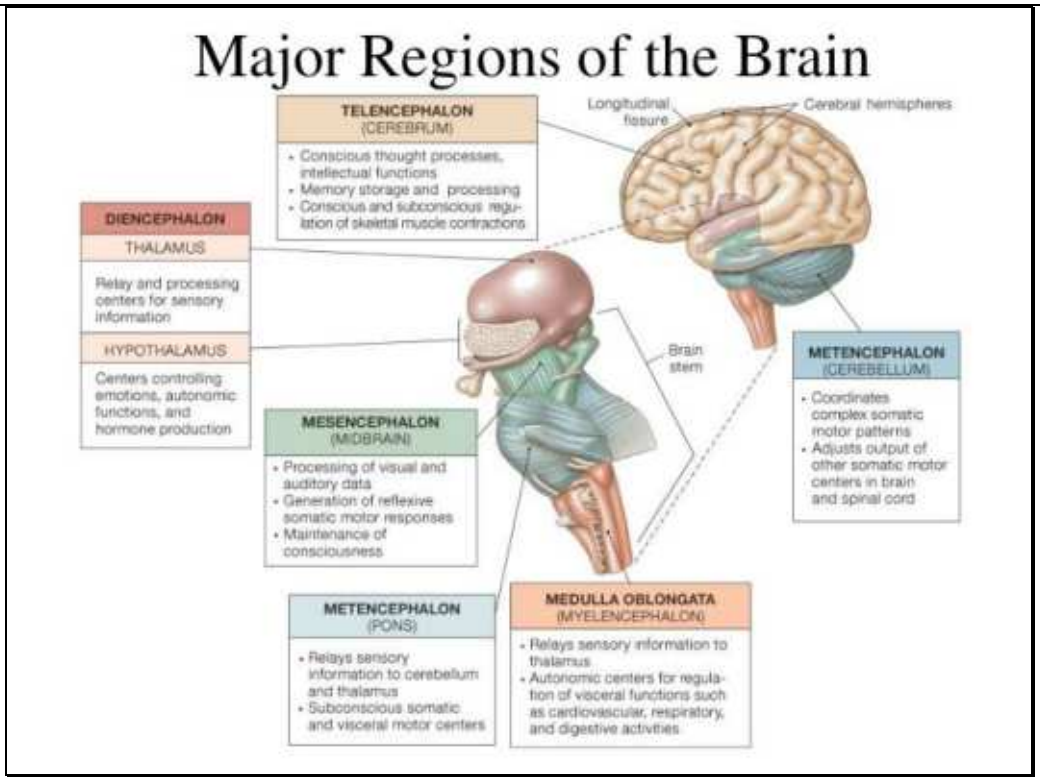


Cluster of Neurons in PNS=Ganglion

Cluster of Neurons in CNS=Nuclei

In order to distinguish nuclei in the gray matter from tracts in the white matter sections of the brain are stained to emphasize either cells or myelinated axons. As can be seen in these histological labeled sections, the cellular organization of the brain consists of the gray matter being on the surface of the brain and as subcortical regions with white matter in between. Whereas in the spinal cord, the gray matter is the most interior region, with the white matter being more exterior.

Slide 6

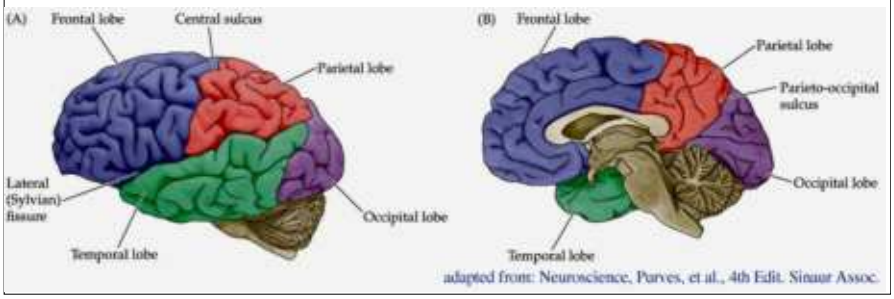


Diencephalon ("between brain") – including the thalamus and hypothalamus
Telencephalon ("end brain") – including the basal ganglia, limbic system, olfactory system, & cerebral cortex
Brainstem (medulla, pons and midbrain) coordinates multiple activities:
Receives sensory input from sensory systems in the head and neck
Provides motor control to muscles of the head and neck
Provides autonomic control to the head, neck and visceral organs
Integrates vital functions such as consciousness, sleep, respiration, circulation, muscle tone & eye movements
Cerebellum (an outgrowth of the pons) plays an important role in:
Coordinating and fine-tuning muscle activity
Learning automatic movements

Slide 7

Cerebrum

- Cerebrum=largest portion
  - Left and right cerebral hemispheres divided by the longitudinal fissure
  - Connected by the corpus callosum
  - Folded into sulci (grooves) and gyri (ridges)
    - Sulci divide the cerebrum into lobes
    - Many gyri and sulci have specific names (ie. Central sulcus)



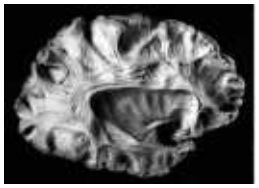
In a lateral view of the cerebral hemisphere, it is useful to subdivide its large area into lobes, corresponding to the cranial bones that cover each of them: frontal, parietal, occipital and temporal. The central sulcus marks the border between frontal and parietal lobes. The lateral fissure marks the border between the temporal and frontal, parietal. The border of the occipital lobe is a line from the parieto-occipital sulcus and the preoccipital notch.

The complexity of folding of the cortical surfaces is directly related to the capabilities of complex thought and behaviors. More folding increases the surface area and number of neurons available in cortex of constant thickness.

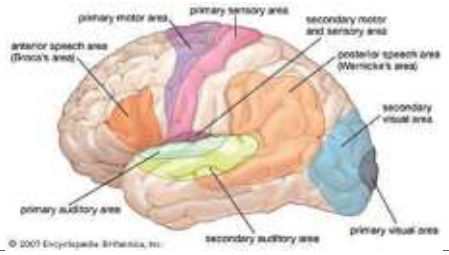
Slide 8

Cerebrum (Cont'd)

- Contains White Matter (axons)
  - Commissural
  - Association
  - Projection



- Contains Gray Matter (neuroglia and neurons)
  - Outermost layer of cerebrum
  - Contains specific gyri for motor and sensory processing
    - Primary somatosensory
    - Primary visual
    - Primary auditory
    - Primary gustatory
    - Primary motor
    - Association Areas

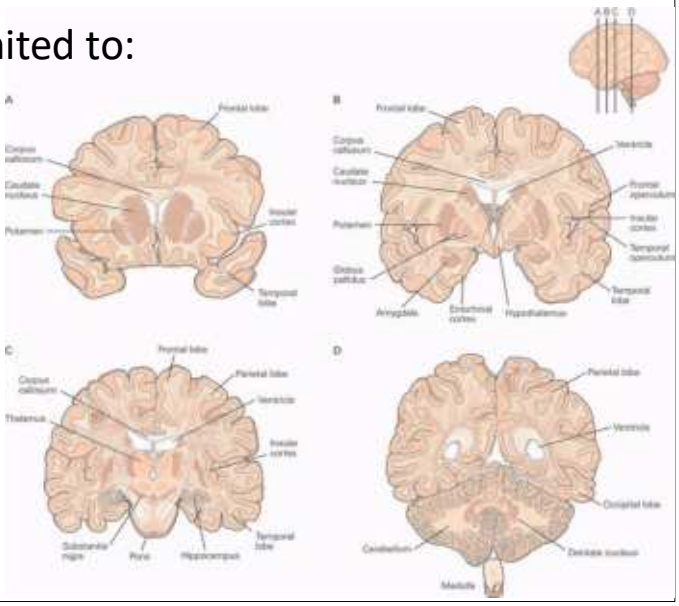


Deep to the cortical gray matter exists white matter (axons). The axons/fibers can be termed based on their locations/connectivity.
Commissural fibers connect the two hemispheres.
Association fibers connect regions within a hemisphere.
Projection fibers are long distance fibers that connect the cerebrum to brain stem, spinal cord, and cerebellum.
The outermost region of the cerebrum is gray matter, which contains neuroglia and neuronal cell bodies. The cerebrum contains regions specific gyri for motor and sensory processing.

Slide 9

Cerebral Gray Matter (cont'd)

- Subcortical Gray Matter
  - aka Nuclei
  - Includes, but not limited to:
    - Substantia nigra
    - Caudate/putamen
    - Globus pallidus
    - Subthalamic nucleus
    - Thalamus
    - Hypothalamus
    - Amygdala
    - Nucleus accumbens
    - Hippocampus
    - Deep cerebellar nuclei
    - Cranial nerve nuclei

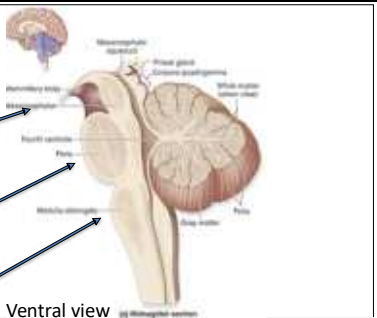


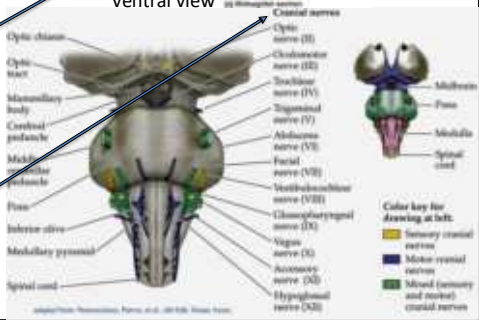
Within the cerebrum exists deep subcortical gray matter regions called nuclei that are associated with functions such as integration of motor commands, initiation and termination of muscle movements, subconscious control of skeletal movement, motor coordination, emotions, cognition, hormone regulation etc.

Slide 10

Brainstem

- Midbrain/mesencephalon
  - Relay station btwn cerebrum & spinal cord; btwn cerebrum & cerebellum
  - Contains nuclei related to motor control
- Pons
  - Bridge between cerebrum & cerebellum
  - Contains nuclei that control both somatic and visceral motor responses
- Medulla
  - Relays sensory information & nuclei controls autonomic functions
  - Posterior nuclei associated with touch, proprioception, pressure & vibration
- Associated with 11/12 Cranial nerves (exception CN I, olfactory)





Brainstem (medulla, pons and midbrain) coordinates multiple activities:

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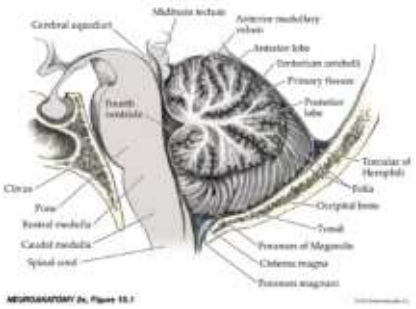
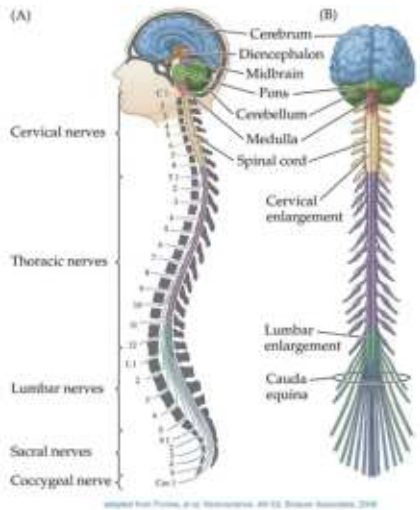
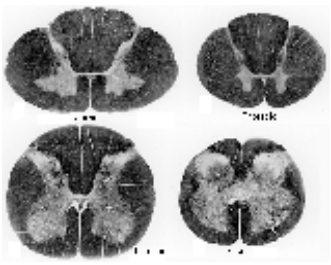
Integrates vital functions such as consciousness, sleep, respiration, circulation, muscle tone and eye movements.

Associated with 11/12 cranial nerves.

Slide 11	**Cerebellum** • Cerebellum: Latin for *little brain* • Cerebellum is important for coordination, precision, and accurate timing of movements but not in their genesis • Receives sensory inputs from multiple sources (ascending) • Receives input related to motor commands (descending) • Receives input also from various brain structures, mostly from areas of cerebral cortex 	Cerebellum send output to motor control systems of cortex and brainstem Cerebellar damage may cause alterations in gait, posture, muscle tone and coordination of the limbs and/or trunk as well as visual symptoms Cerebellum is also involved in some cognitive functions (attention and language), and in some emotional functions.
Slide 12	**External View of Spinal Cord**   Dorsal Surface Ventral Surface ***myelin/white matter stain***	The SC consists of 31 segments, each with dorsal root ganglia (sensory neuron cell bodies), a pair of dorsal roots (sensory afferent fibers), and a pair of ventral roots (motor efferent fibers). Contains cervical (nerves to and from upper limbs) and lumbar (nerves to and from lower limbs) enlargements. Tapers to conus medullaris. Filum terminale arises from the conus medullaris and is an extension of the pia mater that anchors the SC to the coccyx.

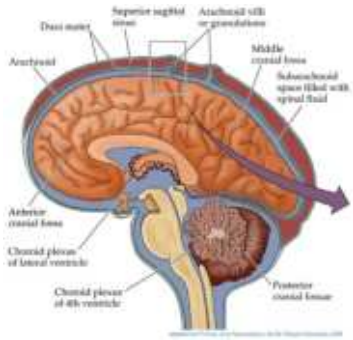
Slide 13

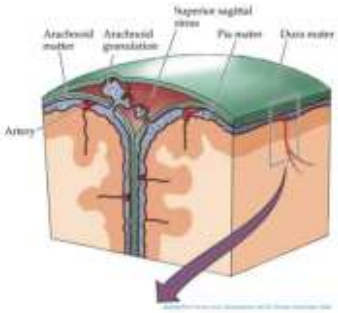
CNS Protection and Support

- Bone: Skull & vertebrae (SFP)
- Meningeal Layers
  - Dura mater
  - arachnoid
  - Pia mater
- Cerebrospinal fluid (CSF)

Slide 14

Meninges





- Dura mater
  - tough connective tissue; tightly adherent to the skull
  - Separate to form dural sinuses
- Arachnoid
  - Thinner, translucent, trabeculated; spans across sulci and cerebral arteries;
  - Subarachnoid space - between arachnoid and pia; filled with CSF; cushions CNS

Pia mater

- Adheres to tissue of brain, thin membrane, limits exchange from ECF and CSF
- Surrounds arteries as they penetrate the brain

In addition to significant protection provided by the skull and the vertebral column, the brain and spinal cord are also protected by multi-layered membranes called the *meninges* and they are cushioned and nourished by *cerebrospinal fluid* (CSF). The brain and spinal cord are covered and protected by three layers of membranes.

Dura – the tough outermost layer which is tightly adherent to the skull, but not tightly attached to the inner part of the vertebral spine. The dura itself has two layers, the outer periosteal layer and the inner meningeal layer.

The space between the arachnoid and the dura, known as the *subdural* space is a potential space. It normally contains nothing but may become filled with blood when veins draining the brain are disrupted.

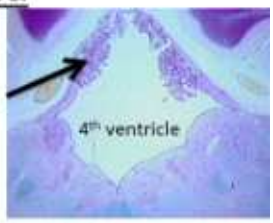
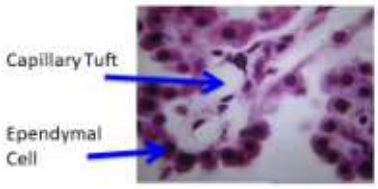
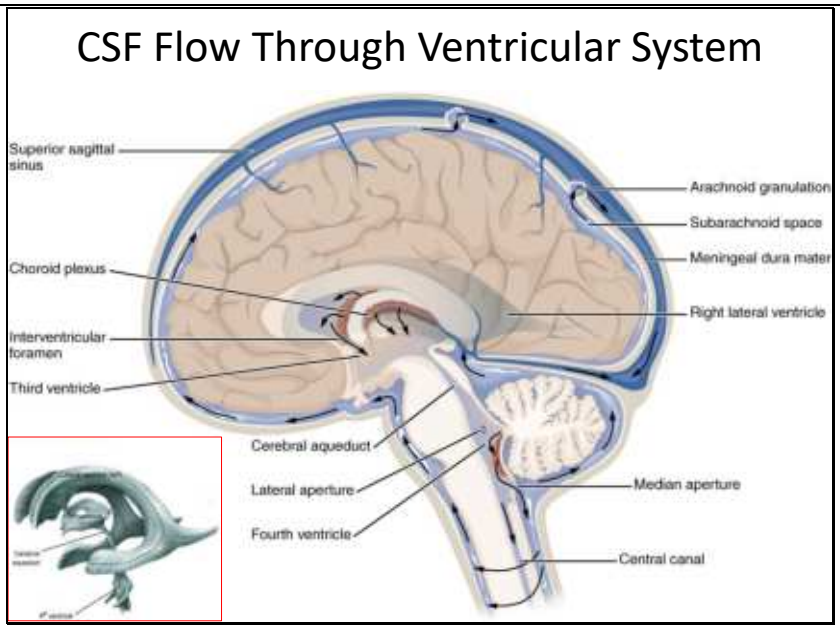
The space between the dura and the skull, known as the *epidural* space is also a potential space. It may become filled with blood when the middle meningeal artery is torn with head trauma; because of higher arterial pressure, epidural hemorrhage is rapidly life-threatening.

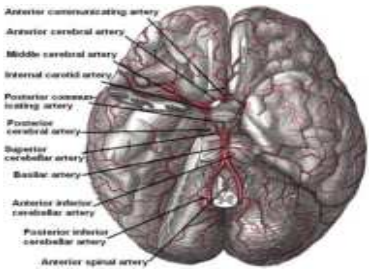
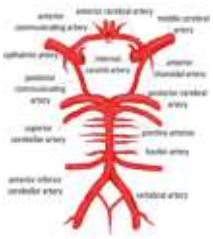
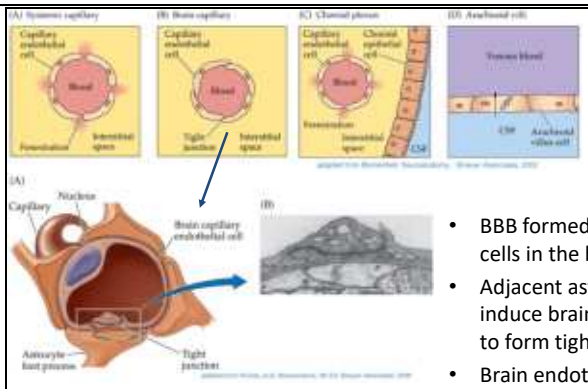
Between two layers of dura in the skull are located the venous sinus which drain the brain.

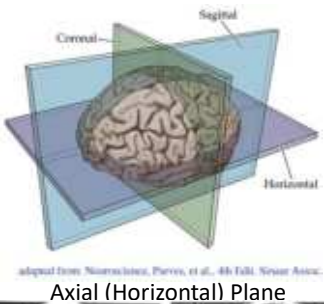
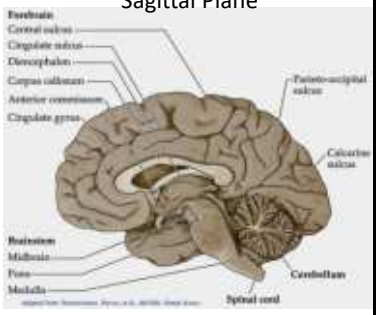
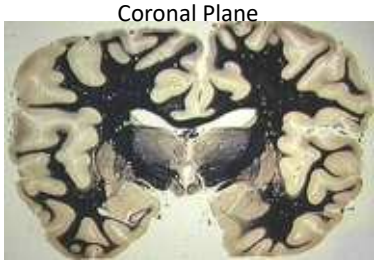
Arachnoid – the intermediate layer which is trabeculated, stretches across sulci (or valleys between gyri of the brain) and contains cerebrospinal fluid in the *subarachnoid* space.

Cerebral blood vessels that rest on the pia may bleed into the subarachnoid space; this is seen with ruptured cerebral aneurysms.

Pia – the delicate, innermost layer which adheres to the surface of the spinal cord and brain and follows all convolutions of the brain.

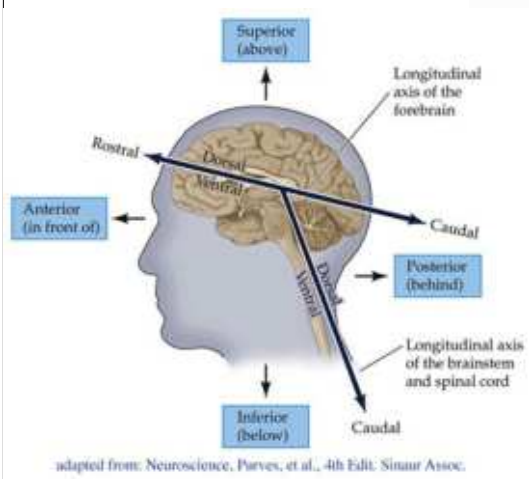
Slide 15	**Cerebrospinal Fluid** • 3 functions: • Buoyant, fluid support for the brain • Cushion against mechanical trauma • Stable metabolic milieu for the brain Table 6-1 Constituents of CSF and Blood Constituent / Lumbar CSF / Blood Na^+ (mEq/L) 148 136-145 K^+ (mEq/L) 2.9 3.5-5 Cl^- (mEq/L) 120-130 100-106 Glucose (mg/dl) 50-75 70-100 Protein (mg/dl) 15-45 6-8 × 10^3 pH 7.3 7.4 CSF, Cerebrospinal fluid   • Not a simple filtrate of plasma • Formed by active transport of ions and small molecules followed by diffusion of water • Most is formed by choroid plexus	CSF is not a filtrate of blood plasma. It is formed through *active transport of ions and small molecules and diffusion* of water. The major constituent of cerebrospinal fluid is water, which enters easily by diffusion. Respiratory gases also enter the CSF primarily by diffusion. For other substances smaller particle size and greater lipid solubility facilitate diffusion. Cerebrospinal fluid originates from many sources, including the pia covering the brain and the extracellular spaces of the brain. Approximately 60% of CSF is formed via choroid plexus in the ventricles. Half of this comes from ependymal cells which line the four ventricles.
Slide 16	CSF Flow Through Ventricular System  	Example: Arterial blood – choroid plexus -- Lateral ventricle – intraventricular foramen (foramen of Monro) – third ventricle – cerebral aqueduct – fourth ventricle – subarachnoid space – arachnoid villi – venous system – heart and lungs – arterial blood –choroid plexus **Remember choroid plexus is located in all the ventricles so CSF can be produced in all of them and then be circulated**

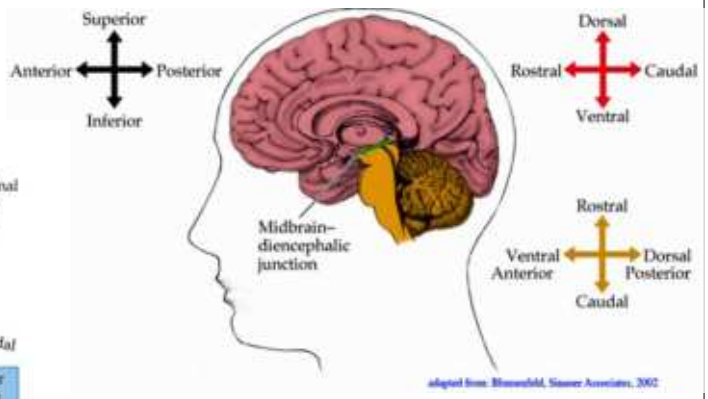
Slide 17	**Blood Supply to the Brain**  • Arterial blood reaches the brain via internal carotids and the vertebral arteries • Arterial Blood to the spinal cord via anterior and posterior spinal arteries • Venous blood leaves via internal jugular veins  Circle of Willis 	Arterial blood input to the brain from the internal carotids and vertebral arteries give rise to the Circle of Willis. The Circle of Willis loops around the optic chiasm connecting the anterior and posterior arterial blood circulation around the brain.
Slide 18	**Blood-Brain Barrier**  • Blood-brain barrier protects CNS tissue from chemical fluctuations in the blood • Negative consequence - drugs are not useful to treat CNS disorders if they do not cross the BBB • BBB formed by capillary endothelial cells in the brain • Adjacent astrocytes foot processes induce brain capillary endothelium to form tight junctions • Brain endothelium coated with p-glycoprotein - negative charges repel many small molecules • Many drugs of abuse are highly lipid-soluble and thus bypass the BBB	The BBB protects delicate CNS tissue from chemical fluctuations in the blood. An undesirable consequence is that it limits use of drugs for treatment of CNS disorders. The blood-CSF barrier system in the choroid plexus was discussed above. The other major barrier is the blood-brain barrier. The surface area of this barrier is about 5000 times greater than the surface area of the blood-CSF barrier. Essential to forming the blood-brain barrier are capillary endothelial cells, which in the brain contain more mitochondria for maintenance of barrier function. Unlike endothelial cells in other organs, those in the brain form an impermeable barrier. Brain enthothelial cells have no fenestrations between them and they form *tight junctions* where cells adhere tightly to each other. On the brain side the endothelial cells are contacted by foot processes of *astrocytes.*

	NOW…TAKE A DEEP BREATHE & STAY TUNED… MORE TO COME 	
Slide 21	Planes of the Brain  Sagittal Plane  Axial (Horizontal) Plane  Coronal Plane 	The central nervous system is bilaterally symmetrical. A perfect slice down the midline would bisect the brain and spinal cord into a right half and a left half that are mirror images. The plane of such a cut is called the sagittal plane*,* and the perspective that this permits is the *mid-sagittal view.* The most notable new feature is the corpus callosum. This is a prominent white matter structure which connects the two hemispheres. The plane of imaging may be rotated 90° so that it is instead cuts through both ears and is parallel to the face. This is called the coronal plane and the series of slices from nose to back of the head are called *coronal cuts.* These are both vertical planes (when a person is standing). A horizontal plane that slices parallel to the floor is called the axial plane and the “cross-sectional” series of slices through the spinal cord or from the base of the skull to the tip of the head are called *axial cuts.*

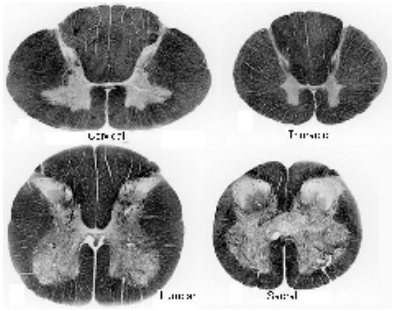
Slide 20

Directional references for the CNS





Dorsal/Posterior Surface



Ventral/Anterior Surface

Terminology of directions and relationships are important in the nervous system. Become familiar with the following pairs of words:

Vertical direction (used because humans stand vertically)

Superior – higher along the axis of the brain / spinal cord, or towards the top of the head

Inferior – lower along the neuraxis or away from the top of the head

Position along the neuraxis (used for humans and for species who do not stand upright)

Rostral – higher along the neuraxis or towards the nose

Caudal – lower along the neuraxis or toward the butt

Horizontal (used in reference to a standing posture)

Anterior – the front of a person who is facing towards you

Posterior – the back of a person who is facing towards you

Perpendicular to the neuraxis (when a person is facing you, arms to the side with palms forward)

Ventral – the front of the head, body, legs, palms and forearms facing you; this is usually the *anterior* part of the body

Dorsal – the back of the head body, legs, soles and back of hands; this is usually the *posterior* part of the body

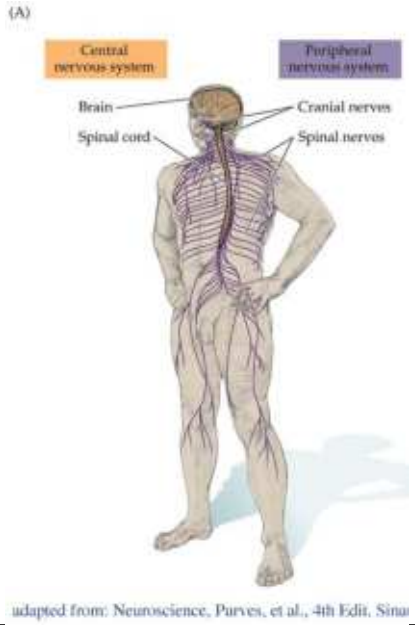
Bending

Flexion -- bending in a ventral or anterior direction

Extension – bending in a dorsal or posterior direction

Slide 21

Directional references for the CNS



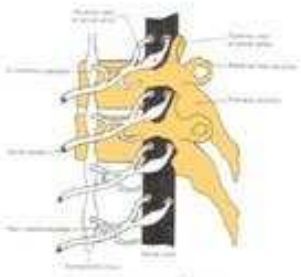
adapted from: Neuroscience, Purves, et al., 4th Edit. Sinu

- Ipsilateral vs contralateral
- Medial vs lateral
- Afferent vs efferent
- Proximal vs distal
- Ascending vs descending

Sidedness
Ipsilateral – structures on the same side of the CNS or body relative to a reference point
Contralateral – structures on the side opposite to the CNS or body relative to a reference point
Laterality
Medial – situated closest to the midline of the body
Lateral – situated closest to the left or right side of the body
Movement of information
Afferent – conveying impulses inward, towards the highest level of the nervous system
Efferent – conveying impulses outward, away from their origin in the nervous system
Using these terms, it is possible to understand the position of the brain relative to the spinal cord. At the point where the spinal cord meets the brainstem, there is a *ventral* concave bend (anterior bending, or *flexion*) called the cervical flexure. More *rostrally* at the level of the midbrain there is another *ventral* concave bend called the cephalic flexure.
There are two other word pairs that apply primarily to nerves and structures in the arms and legs:
Position relative to the center of the body
Proximal – closer to the body
Distal – further from the body
Movement in a vertical direction
Ascending – moving towards the head, proximally; up the neuraxis
Descending – moving down the body, distally; down the neuraxis

Slide 22

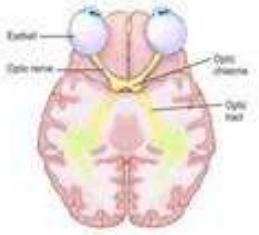
Clarification of Nervous System Terms



Ganglion
A group of neurons outside the CNS

Nucleus
A group of neurons within the CNS

Nerve
A group of nerve fibers (axons) outside the CNS



Tract
A group of nerve fibers (axons) within the CNS