

This Chapter is intensive in definitions and details again

recommend you make a list of the definitions in your own words (like on index cards with word on one side and your definition/description on the other side)

We will discuss:

Basic Features of the Nervous Systems

such as the meninges, the ventricles, CSF

The CNS

development of brain, the lobes, forebrain, midbrain and hindbrain, spinal cord  
(Note in this picture that the frontal lobe is red, the parietal is green, the occipital is orange, the temporal is purple; the cerebellum is in the back in reddish-orange and the spinal cord is outlined in white).

The PNS

Spinal nerves, cranial nerves, autonomic nervous system (sympathetic & parasympathetic).

## Chapter 3: Structure of the Nervous System



Group work: List 1-2 functions of each of the 4 brain lobes

The cerebral cortex is divided into four lobes.

Frontal: movement & planning of movements, executive function, inhibition  
speech production (Broca's) in fronto-parietal (& organization/planning & personality)

Parietal: somatosensory

Occipital: vision

Temporal: emotion, motivation, learning, olfaction, audition  
speech comprehension (Wernicke's) temporo-parietal

Most thought and perception take place as nerve impulses, APs, which move across and through the cortex.

## Key Definitions

- Nerve: collection of axons outside CNS
- Tract: collection of axons inside CNS
- Nucleus: collection of cell bodies inside CNS
- Ganglion: collection of cell bodies outside CNS

Keep these in mind as we go through the CNS and PNS structures and functions

Note that there are many more important definitions for this Chapter. Use the textbook, Study Guide, and/or these slides to give you idea of which are most important.

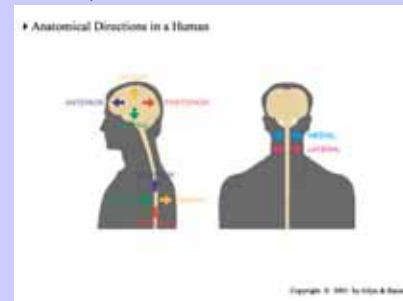
Nerves such as the cranial nerves and spinal nerves that are in the PNS

Red nucleus of the midbrain, for example

Dorsal root ganglion of the spine that contains afferent sensory fibers, e.g.

## Neuroanatomy Terms

- The **neuraxis** is an imaginary line drawn through the spinal cord up to the front of the brain
- Anatomical directions are understood relative to the neuraxis
  - Anterior (rostral): toward the head
  - Posterior (caudal): toward the tail
  - Ventral (inferior): toward the “belly”
  - Dorsal (superior): toward the back (top of head)
- Location in brain:
  - Ipsilateral: same side of brain
  - Contralateral: opposite side of brain



I visualize caudal as the posterior (your rear) and think of rostral as near the nose (more front)

Think of a dolphin's dorsal fin to remember dorsal is on top; Rostral for rosy nose was a mnemonic we came up with in 2003.

Caudal (posterior): Rostral (anterior) :: Dorsal (superior top): Ventral (inferior belly)

Medial is toward the middle; lateral is toward the sides of the body.

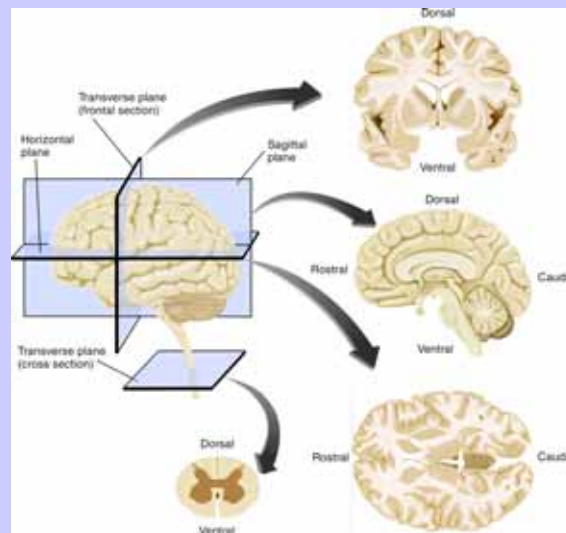
Q. We had one example so far of an ipsilateral pathway. Can you remember what it was?

Hint...it was in relation to consciousness

A. While movement of the body parts are controlled contralaterally (I.e. right hemisphere controls movement of left side of body), the sense of smell is perceived by the same side, or ipsilateral hemisphere (I.e. in the right nose, processed by the right hemisphere).

## Planes of Section

- The brain can be sectioned in three planes
- Each section provides a different view of the internal anatomy of the brain
  - Sagittal
  - Coronal (or transverse)
  - Horizontal



Sagittal section is a slice perpendicular to the ground (think of this one as dividing the brain into two symmetrical halves). This is like a side view. A split-brain patient would have a mid-sagittal cut to sever the corpus callosum in hopes of relieving epileptic seizures.

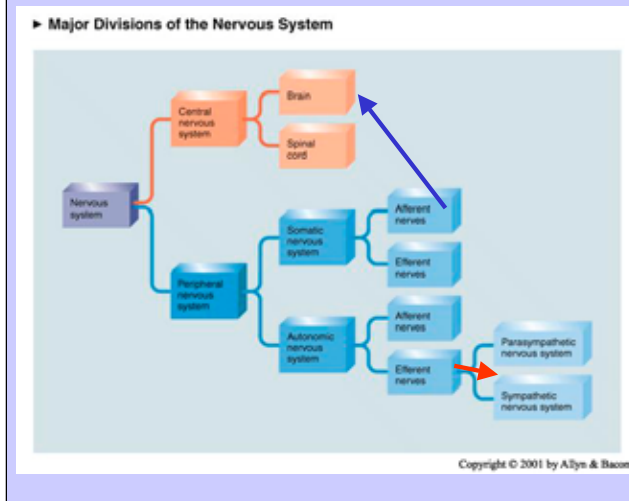
Coronal or transverse frontal section is a cut parallel to the forehead. With this cut you get a dorsal (top) and ventral (bottom) look at the inside of the brain. This is how most brain sections are made in rat brain studies.

Note. A cross-section of the spinal cord looks similar to the coronal cut because of our upright posture.

Horizontal is a slice through the brain parallel to the ground. This would be like the cut that was taken in the movie Hannibal. Cutting in the middle of the brain (mid-sagittal) would result in a slice of brain like the yellow (or green Martian brain) jello mold I showed you in class.

## Two Nervous Systems

- The nervous system consists of two divisions
  - The central nervous system (CNS) is comprised of the brain and spinal cord
  - The peripheral nervous system (PNS) is comprised of the cranial/spinal nerves and peripheral ganglia



- PNS divided into Somatic & Autonomic Nervous Systems
- PNS nerves project to target organs and to muscles (**efferent: motor**)
- These nerves also carry sensory information to the brain (**afferent: sensory**)

### An overview

The CNS: Spinal cord is a conduit for information to and from brain

Remember that the brain, protected by the skull, has neurons, glia, and other supporting cells. It is also protected by the blood-brain barrier (chemical guard), covered by meninges, and floats in cerebrospinal fluid.

The PNS: nerves and ganglia outside the CNS covered by dura mater and pia mater.

Somatic NS- receives sensory info and controls movements of the muscles

Autonomic NS- self-governing system that regulates muscles and glands

Afferent (arriving) nerves-incoming: **sensory** info into the CNS

Efferent (exiting) nerves-outgoing: **motor** axons out {Think “me”}

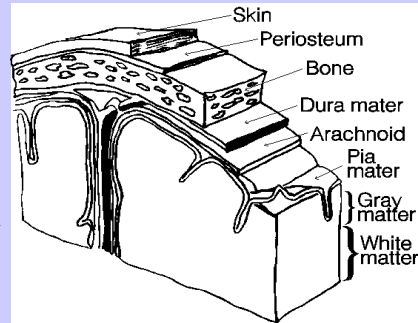
Efferent (exiting motor info) in the PNS (part of Autonomic Nervous System) further subdivided into the

Parasympathetic NS – relaxation (e.g. slows heartbeat, stimulates digestive system) or increases in stored energy

Sympathetic NS – Excitement or exertion (e.g. increased heart rate)

## The Meninges

- The brain and spinal cord are protected by a series of membranes termed **meninges**
  - Dura mater-outer (thick) layer
  - Arachnoid-middle layer
    - Overlies the arachnoid space (CSF)
    - Blood vessels run through the arachnoid layer
  - Pia mater- inner layer
    - Overlies every detail of the outer brain



Source: Brain Tumor Foundation of Canada. <http://www.btfc.org/>

The entire nervous system is covered by connective tissue; the protective sheaths around the brain and spinal cord are the meninges.

From the skull down into the brain the three layers of meninges are:

Dura mater (hard mother) tough but unstretchable

Arachnoid membrane (spider-like track) soft and spongy

Gap called the subarachnoid space filled with CSF that acts as a cushion for the brain

Pia mater (pious or delicate mother) smaller blood vessels of brain & spinal cord

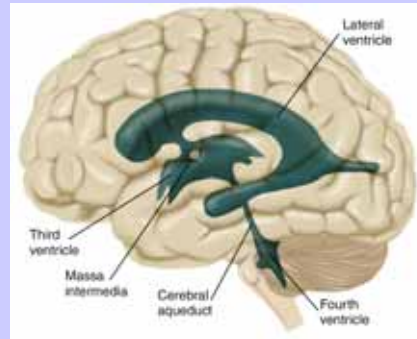
Pia mater is like cellophane (Saran Wrap) covering the brain

CNS vs. PNS covering differs --

PNS only has 2 layers of meninges: a fused dura and pia mater.

## Cerebrospinal Fluid

- The brain floats in a pool of **cerebrospinal fluid** (CSF) which reduces its net weight from 1400 g --> 80 g
- CSF is also contained within four brain ventricles



- CSF is produced by the **choroid plexus** of each ventricle
- The brain ventricles are an access point for drug studies
- The brain ventricles can expand when brain cells are lost (as in alcoholism or certain diseases).

Remember that CSF is important for cushioning the brain (reduces shock like from sudden head movement as in a case of whiplash).

Ventricles are interconnected chambers filled with CSF. 3<sup>rd</sup> ventricle is at the midline of the brain. The cerebral aqueduct connects the 3<sup>rd</sup> & 4<sup>th</sup> ventricles.

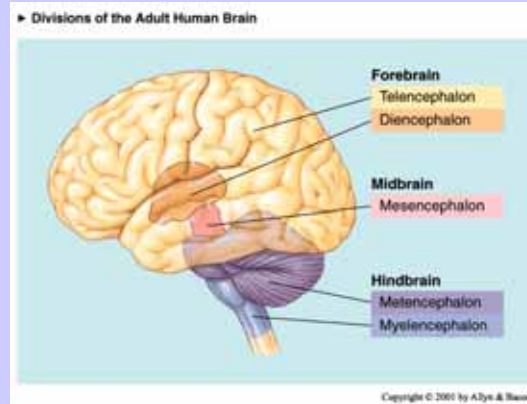
Special tissue called the choroid plexus, in each of the ventricles, that is rich in blood manufactures the CSF, which itself resembles blood plasma.

CSF is continually produced, circulated and reabsorbed when there is no damage in the brain. Without proper circulation and reabsorption, you get an increased pressure buildup and one result is the 'water-head syndrome' known as hydrocephalus (not too much water actually, but too much CSF).

An overswelling of the ventricles is indicative of damage (remember from the neuroimaging scans) as in Alzheimer's disease, alcoholism, and hydrocephalus for example.

## Brain Development

- The nervous system develops from **ectoderm** (outer layer) which forms a plate (~ day 18)
  - fuse together forming a neural tube
  - By ~ day 28, the neural tube has formed the ventricles and the tissue surrounding them has formed three major divisions of the brain
    - **Forebrain**, **midbrain**, and **hindbrain**



NS development begins about 18 days after conception from the back outer layer of embryo

21-day-old embryo: The edges of the plate curl and eventually fuse together forming a **neural tube**, which results in the brain and spinal cord.

Neural tube is the origin of the CNS!

The cerebral cortex is the bark that covers the two hemispheres (part of forebrain). Labeling studies have shown that cortex develops from the inside out (I.e. newest cells must pass through all the layers to get to the outer surface). Guided along by radial glia and founder cells (give rise to neurons).

Important concept is **apoptosis** (or programmed cell death)

Apoptosis is a chemical signal that stops cortical development by activating killer genes within the cells.

Then connections are formed via growth cones. Remember there's an over abundance of neurons, so those axons (of neurons) that don't make connections die off by apoptosis.

It's a fight to establish a (synaptic) connection that is similar in reproduction (sperm fighting for the egg).

## Overview of the CNS

### Forebrain:

Cerebral Cortex

Basal Ganglia      Lateral ventricle

Limbic System

Thalamus              Third ventricle

Hypothalamus

### Midbrain:

Tectum                  Cerebral aqueduct

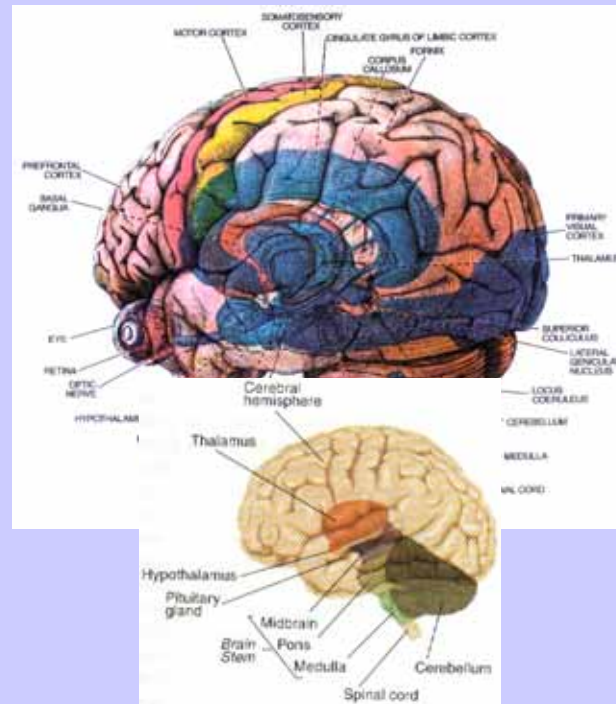
Tegmentum

### Hindbrain:

Cerebellum            Fourth ventricle

Pons

Medulla



Refer to Table 3.2 on pg. 73: The major divisions and principal structures should be your focus

The color coding goes with the smaller picture, seen on pg. 73. The larger picture is a cool brain graphic and represents the forebrain structures much better.

Division into the following sections:

Forebrain Telencephalon: (Cerebral cortex, Limbic system), Diencephalon : Thalamus, Hypothalamus

Midbrain (Mesencephalon: Contains tectum & tegmentum)

Hindbrain (Metencephalon)

## Cerebral Cortex

- The **cerebral cortex** forms the outer surface of the cerebral hemispheres
- Cortex surface is convoluted by **grooves**
  - **Sulci** (small grooves)
  - **Fissures** (large grooves)
- The **bulges** in cortex are termed **gyri**
- The cortex is primarily composed of cells, giving it a gray appearance
- Cortex can be divided into 4 lobes:
  - frontal, parietal, occipital, and temporal

Cortex is the most visible part of the brain. Surface area is 2.5 sq. ft. Its about 3mm thick. Mostly somas, dendrites, glia

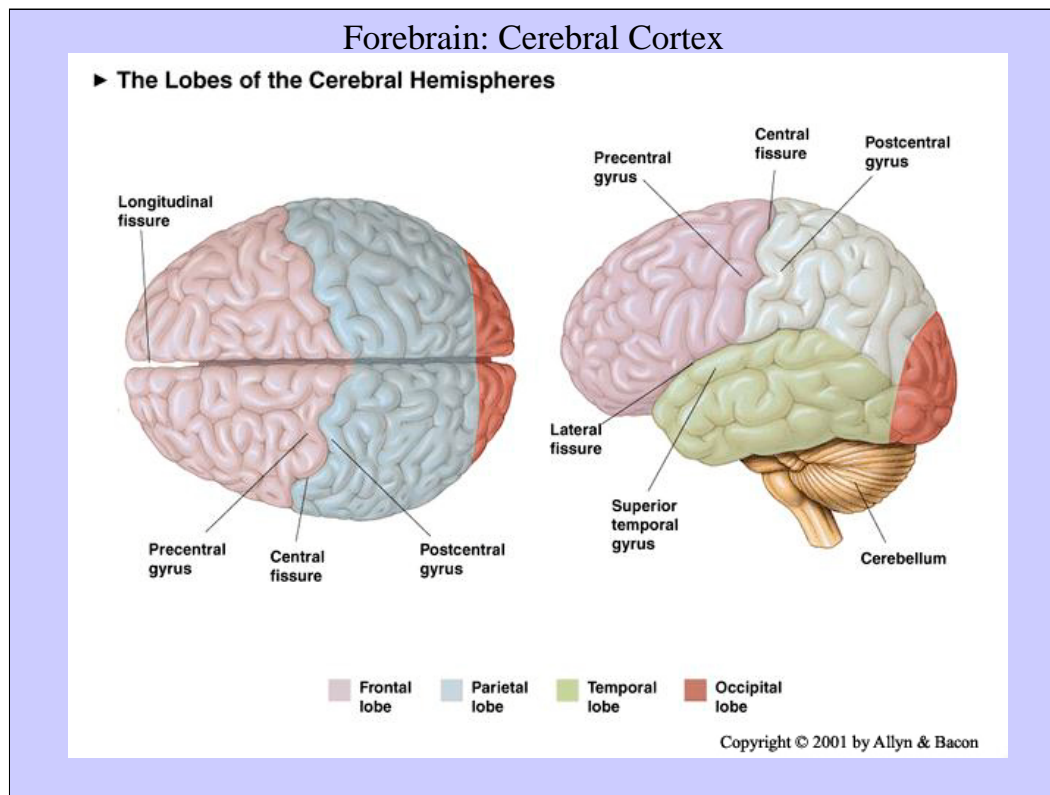
and interconnecting axons giving it a brownish gray color.

Underneath it are masses of myelinated axons, which have a whiteish appearance. (Subcortical region).

Gray matter=cell bodies (somas) on the outside of the CNS (reverse in spine)

White matter=axons and myelin on inside of CNS (reverse in spinal cord)

The cerebral cortex ('bark') covers the 2 cerebral hemispheres which can be divided into four lobes: Frontal, Temporal, Parietal and Occipital (see next slide)



The four lobes of the cerebral cortex:

Frontal lobe: front

Includes everything in front of central sulcus / fissure

Primary motor cortex & motor assoc cortex

Creating & planning movement

& prefrontal cortex (rostral to motor association area) does strategic planning

Parietal lobe: the wall

Primary somatosensory cortex & somatosensory assoc. cortex

Temporal lobe: the temple

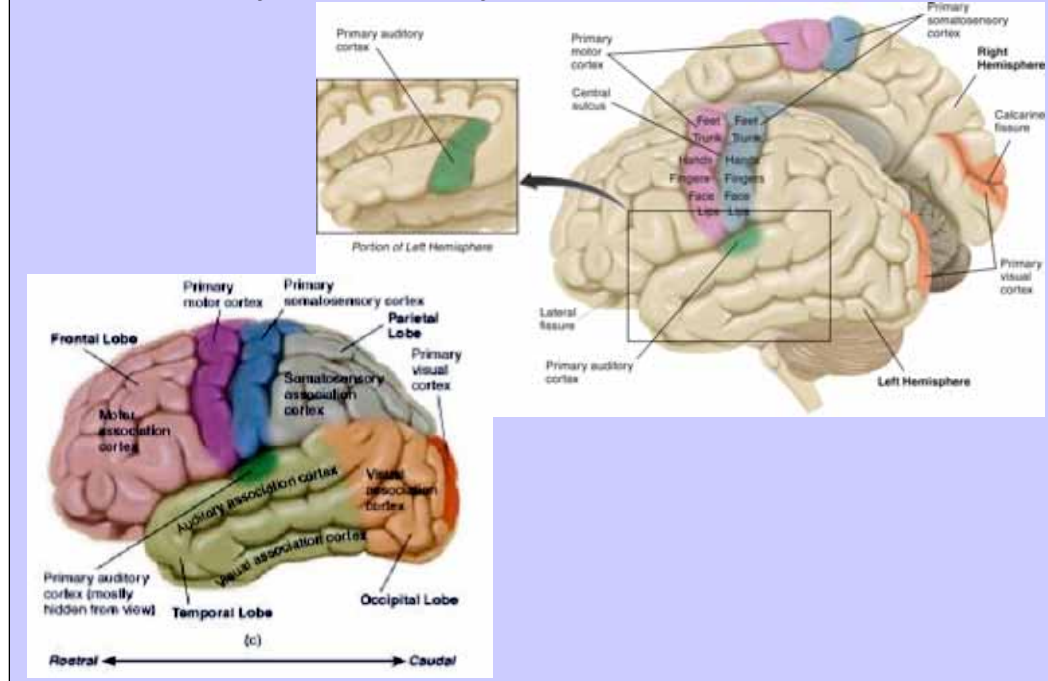
Primary auditory cortex, Auditory association cortex + visual association cortex

Hearing, seeing, emotion, learning and memory to name a few

Occipital lobe: back of head

Primary visual cortex + visual association cortex

## Primary Sensory and Motor Cortex



Primary sensory cortex located in parietal lobe: Deals with perception of touch, arranged like homunculus (little man—not shown here, see pg. 253).

Maps to different areas of body (Remember all sensory pathways EXCEPT olfaction—smell— are contralateral connections).

Primary motor cortex located in frontal lobe: Can be stimulated to produce movements.

Motor association cortex deals with planning of motor activity

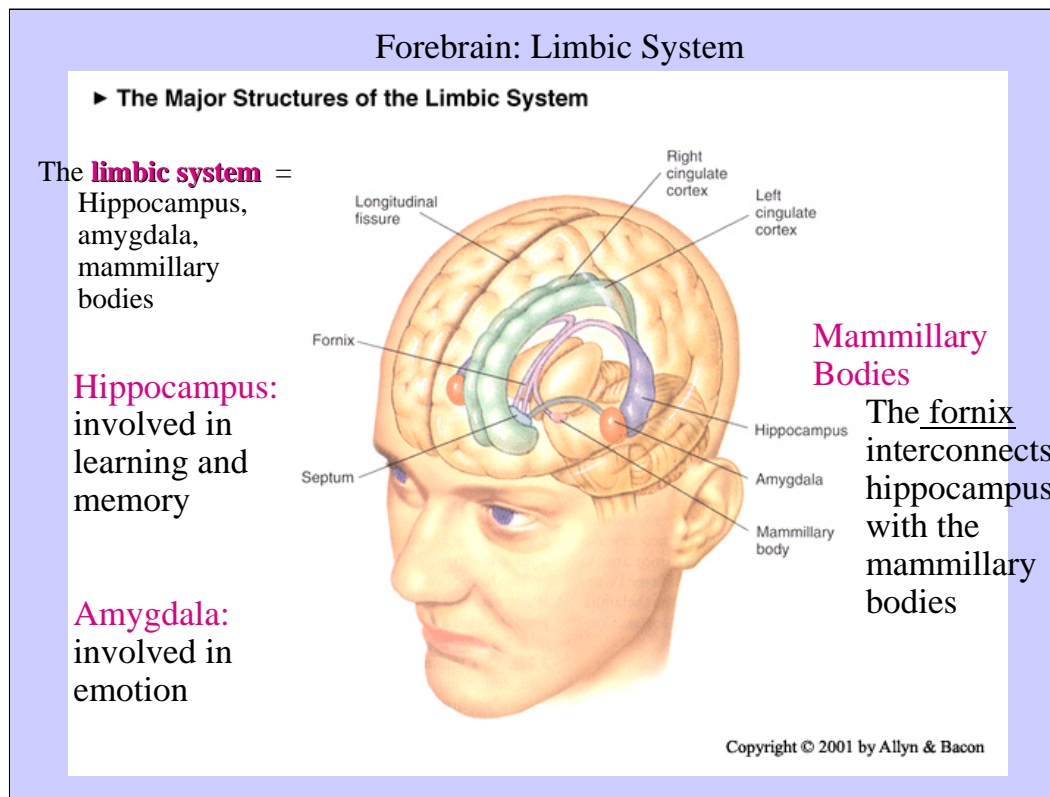
Separates the frontal and parietal lobes with central sulcus on top of head.

Association cortices (all other lobe areas that are not primary) deals more with interpretation of sensations i.e. perception. Association ~ integration areas

Temporal lobe : Left normally language related, Right dealing with spatial & synthesis skills.

Note. Brain Asymmetry: Right Hemisphere is good with synthesis, putting things together as whole (maps) whereas the Left Hemisphere is good with analysis of info. & serial things like talking and speaking (verbal abilities).

Visual area deal with visual sensation and visual perception (decoding visual information).



Limbic cortex, hippocampus, amygdala.

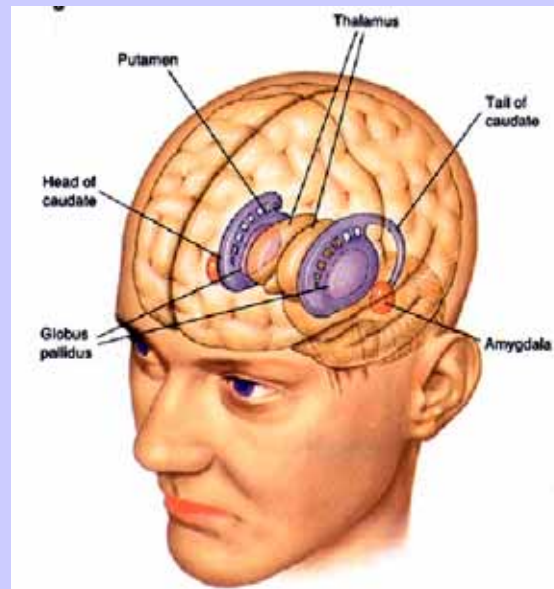
Fornix links hippocampus with other areas, inc. mammillary bodies. Mammillary bodies linked with the hypothalamic nuclei (Autonomic NS and sex hormones)

Hippocampal formations & part of limbic cortex deals with learning and long-term memory storage.

Amygdala & other parts of limbic cortex deals with emotion (including perception of memories & emotional memory)

## The Forebrain: Basal Ganglia

- The **basal ganglia** are a collection of subcortical nuclei that lie just under the anterior aspect of the lateral ventricles
- Basal ganglia consist of:
  - Globus pallidus
  - Caudate nucleus
  - Putamen
- Basal ganglia are involved in the control of movement



Pale globe=Globus pallidus

Nucleus with a tail=Caudate Nucleus

Shell=Putamen

Involvement in control of movement mean that these areas are important in cases of Parkinson's disease.

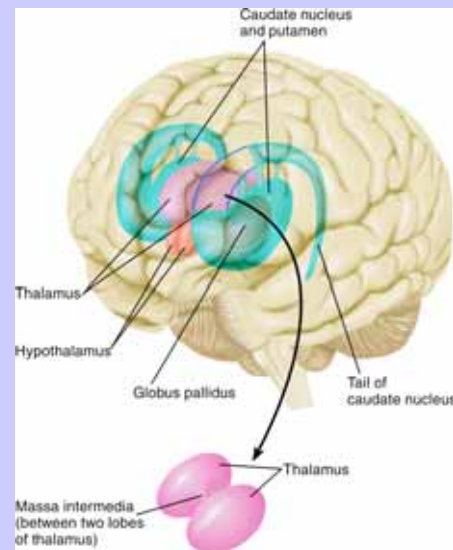
Parkinson's patients have loss of balance, tremor, rigidity associated with the basal ganglia.

Basal ganglia also happens to be the area of the brain that allows us to smile naturally, like from laughing spontaneously. A stroke patient without damage to the basal ganglia will be able to smile perfectly normal when laughing, but when asked to produce a smile (like in front of a camera without natural humor), then the typical stroke drooping on one side of the mouth will be seen.

So when smiling for the camera, remember to laugh first so you can have a natural basal ganglia smile!

## Forebrain: Thalamus & Hypothalamus (3rd Ventricle=Diencephalon)

- **Diencephalon** consists of
  - **Thalamus**: contains nuclei that receive sensory information and transmit it to cortex
  - **Hypothalamus**: contains nuclei involved in integration of species-typical behaviors, control of the autonomic nervous system and pituitary



This surrounds the 3rd ventricle and is the second major division of the forebrain. Literally the diencephalon means “inter-brain”.

Thalamus has 2 lobes, connected by massa intermedia (runs through 3rd ventricle) which is missing in many people !

**Thalamus is a sensory switchboard of the brain.**

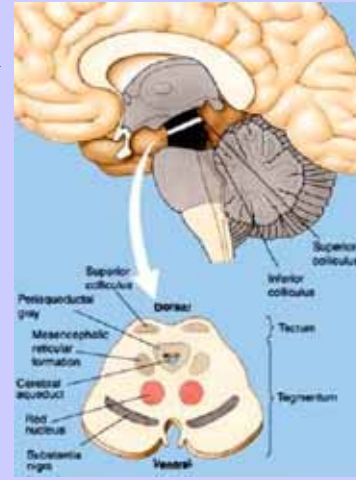
Hypothalamus=arousal and hormone release

Hypothalamus is involved in arousal (Autonomic NS)- the 4 F's : Fight, Flee, Feed and Fornicate--this is most likely the interaction of both the sympathetic (Fight, Flight, and 'Mating') and parasympathetic (Feed) systems.

It attaches to the pituitary gland - where many hormones are made including gonadotropic glands (sex hormones) etc.

## Midbrain: Tectum & Tegmentum (Cerebral Aqueduct=Mesencephalon)

- The **mesencephalon** (midbrain) consists of
  - **Tectum** is the dorsal portion of midbrain
    - Superior and inferior colliculi are involved in the visual and auditory systems, respectively
  - **Tegmentum** is the portion of the midbrain located under the tectum and consists of the:
    - Rostral end of the reticular formation
    - Periaqueductal gray
    - Red nucleus
    - Substantia nigra



Also called the Mesencephalon, this surrounds the Cerebral Aqueduct.

Q. What kind of cut is shown here? A. Transverse (or Coronal=parallel to frontal lobe)

Tectum (roof) includes superior and inferior colliculus. Appear as 4 bumps on the dorsal surface of the brainstem. Brainstem=Midbrain, Pons, Medulla

Superior colliculus involved in vision, Inferior involved in audition

{mnemonic: vs & ai}

Tegmentum (covering) includes

Reticular formation-little net=interconnected network of neurons with lots dendrites and axons: role in sleep, arousal, muscle tone, movement & vital reflexes

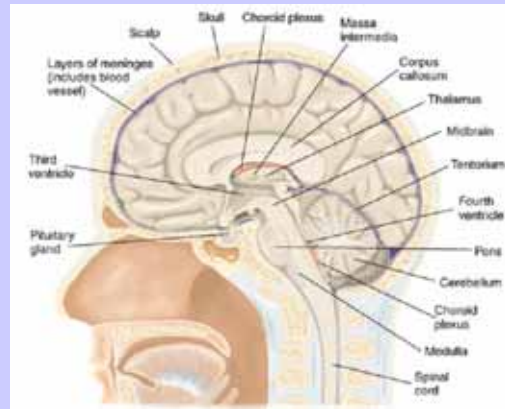
& Periaqueductal **gray**: control fighting / mating behavior movements; opiates have there pain reducing effect in this area!

& Red nucleus: motor info...info from cerebral cortex & cerebellum to spinal cord

& Substantia nigra: motor info..Degeneration in the substantia nigra (sending projections to caudate nucleus & putamen) causes rigidity, tremors, poor balance and inability to initiate movements=Parkinson's Disease

## Hindbrain: Pons & Cerebellum (4th ventricle=Metencephalon)

- Metencephalon consists of the
  - Pons
    - Contains the core of the reticular formation
    - The pons is involved in the control of sleep and arousal
  - Cerebellum is involved in motor control



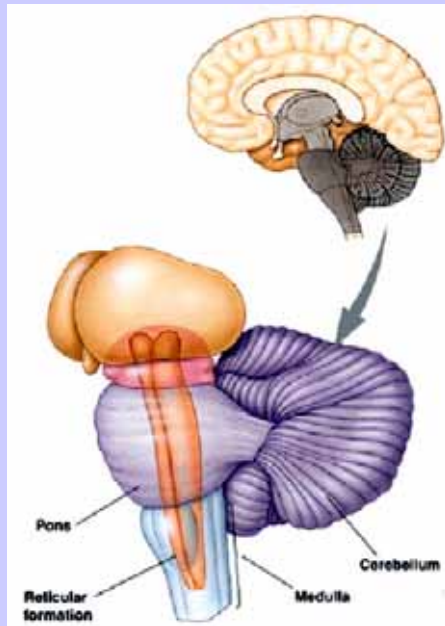
The 4th ventricle, made up of metencephalon and myelencephalon Metencephalon contains

Pons: (bridge) Contains part of reticular formation:sleep & arousal. Damage to this can cause coma or death.

Cerebellum: (**Little brain**) involved in controlled / coordinated movements. Has cerebellar cortex, and deep cerebellar nuclei (receive projections from the cerebellar cortex and project to other parts of the cerebellar cortex, and other parts of the brain) Attached to surface of pons via cerebellar peduncles (little feet).

Cerebellum receives lots of info from senses and modifies motor outputs. Damage results in poorly formed jerky movements. Extensive damage makes standing, walking, reaching etc. impossible.

## Hindbrain: Medulla



- The **myelencephalon** consists of the
  - **Medulla** oblongata
    - The medulla is the most caudal portion of brain and is rostral to the spinal cord
    - The medulla contains part of the reticular formation
    - The nuclei of the medulla control vital functions such as regulation of the cardiovascular system, breathing, and skeletal muscle tone

Myelencephalon - (Marrow brain)

Contains Medulla Oblongata (oblong marrow) controls vital functions  
breathing, heartbeat / blood pressure, skeletal muscle tonus

Medulla is part of the brainstem..... If this breaks - you die !



## Central Nervous System in Review

- Development of NS is genetic, but environmental stimulation contributes
  - Apoptosis: genetic program that halts cellular development
- The brain has lateralized functions (egs. Lobes, primary strips) & has asymmetry (egs. Left:analyze :: Right:synthesize, in general)
- Brain is 'plastic', I.e. malleable and changeable with experience
  - Use it or lose it (it's never too late to learn 😊)

Key concepts about the CNS are reviewed here (new 6/2004).

## The Peripheral Nervous System

- **Somatic** division of PNS is comprised by nerves that control **muscle** action and that carry **sensory** information back to the CNS
  - Cranial nerves (12)
  - Spinal nerves (31)
- **Autonomic** division of PNS governs smooth muscle and gland secretion
  - **Parasympathetic**: supports activities that increase energy
  - **Sympathetic**: arousal and the expenditure of energy

12 pairs of cranial nerves (PNS) are attached to ventral (under-belly) of the brain. Most of cranial nerves serve sensory and motor functions of head and neck. There are efferent (motor) fibers and afferent (sensory) fibers. E.g. sense of taste is received via cranial nerves from unipolar neurons.

Spinal nerves—Begin at the junction of dorsal and ventral roots of spinal cord.

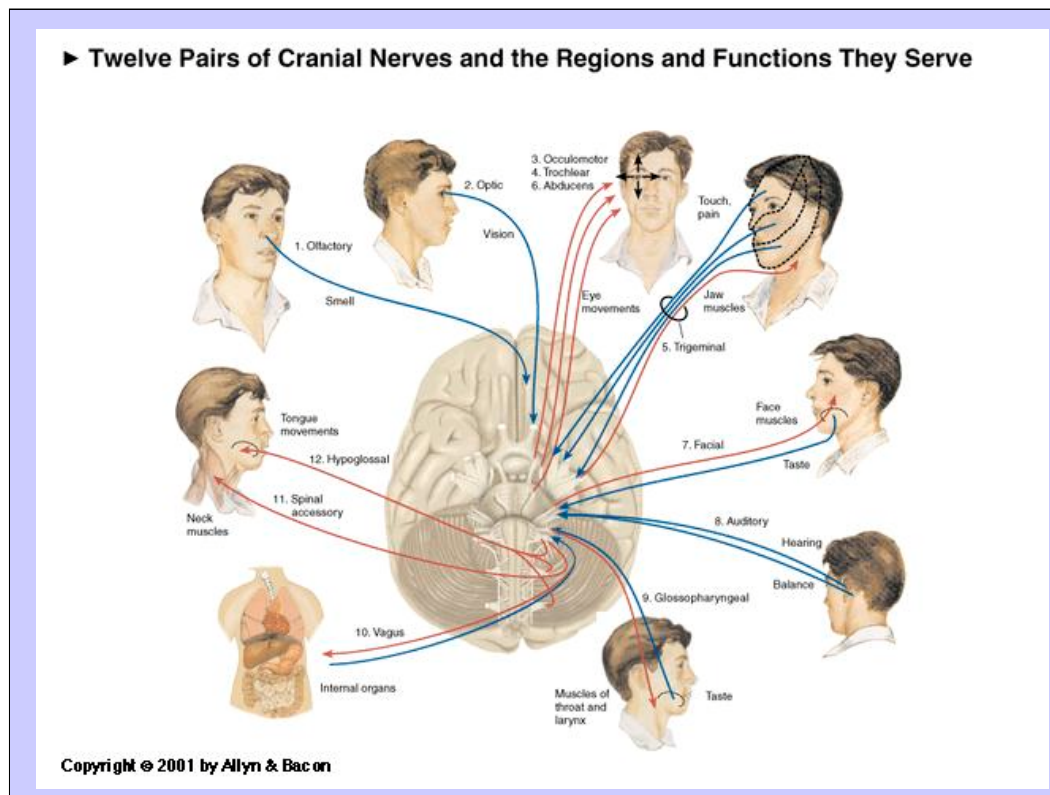
Somas of all axons that bring sensory info **into** the CNS (brain and spinal cord) are located *outside of the CNS*, exception is the visual system (retina). These are the **afferent** axons (arriving in the CNS) from the dorsal root ganglia (unipolar neurons).

Dorsal root=somatosensory info

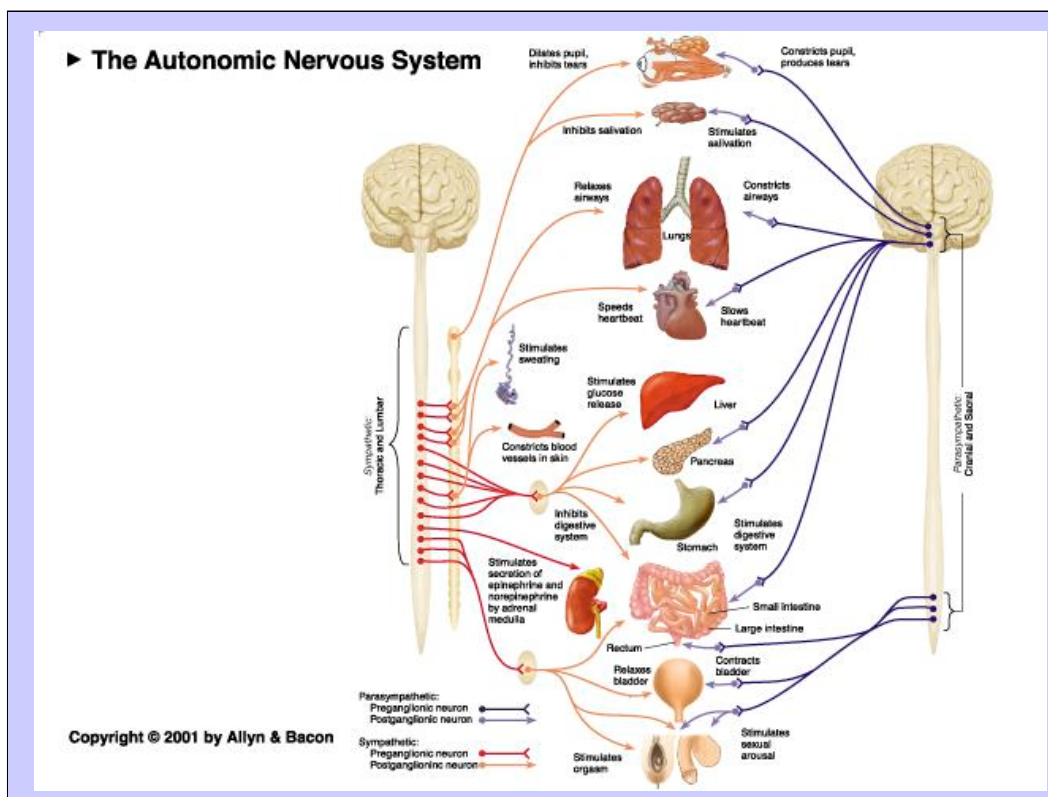
Somas that go to the ventral root are in the gray matter of the spinal cord (multipolar neurons). These are **efferent** axons because they exit the CNS.

Ventral roots=control of muscles and glands

Autonomic regulates skin, blood vessels, eyes, gut, gallbladder, urinary bladder for instance. The ANS has two separate systems; both usually act on each organ to produce a different effect. Sympathetic speed heart rate whereas parasympathetic serves to slow heartbeat.



To help you study the cranial nerves you can use this graphic. Note for this BB1 class you do NOT need to memorize all 12 cranial nerves. Note where they are located, what they do, and the afferent and efferent connections.



ANS with parasympathetic and sympathetic projections. Each system acts slightly differently on all the major organs.

Sympathetic is the 'energetic' system while

Parasympathetic is more about conserving energy or energy buildup.

## The Autonomic Nervous System

- **Parasympathetic** division
  - Associated with energy conservation
  - Derives from cranial and sacral levels of the spinal cord
- **Sympathetic** division
  - Associated with energy expenditure
  - Derives from thoracic and lumbar levels of the spinal cord

Parasympathetic—the relaxed energy store—secretes acetylcholine.

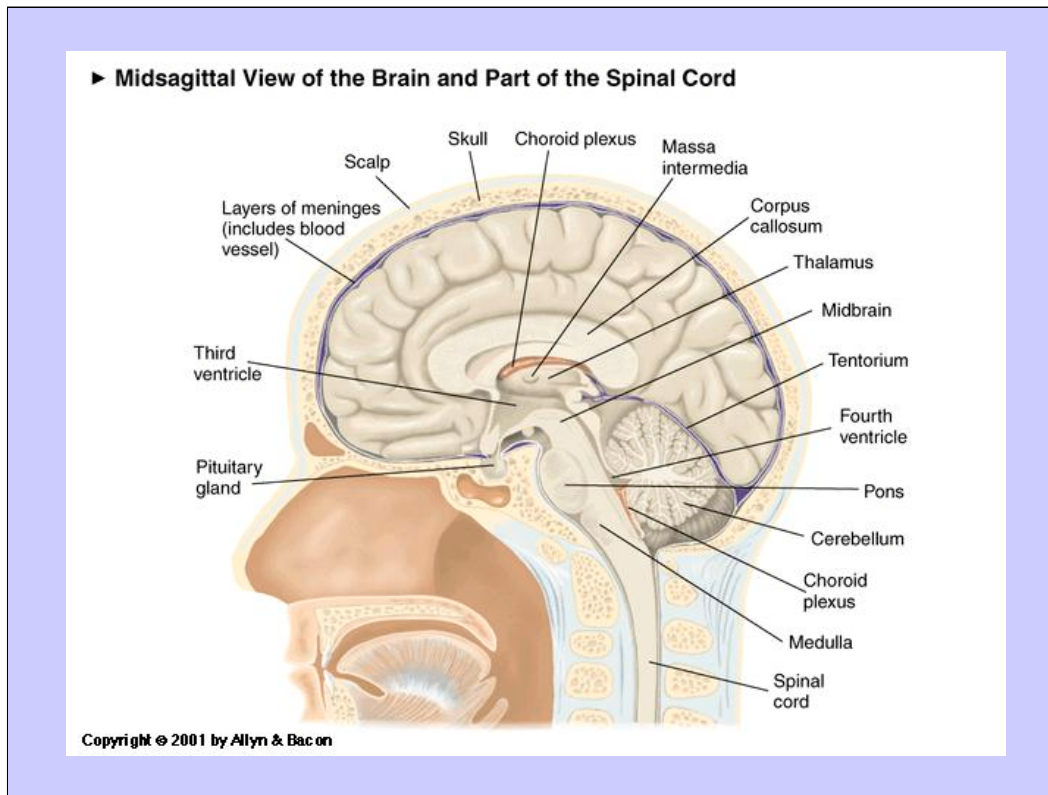
Parasympathetic systems produces tears, stimulates digestion etc.

Somas are located in cranial nerves (like vagus) and gray matter of sacral region of spinal cord (craniosacral system).

Sympathetic –the energetic one– stimulates secretion of epinephrine. This gives us goosebumps (among other energy expenditures like rise in blood sugar).

Cell bodies (somas) of sympathetic motor neurons are from gray matter in lower regions of the spine (thoracolumbar system). The neuron fibers pass through the sympathetic ganglion chain (left on Fig. 3.25).

The adrenal medulla (on top of kidneys) is also controlled by sympathetic fibers; it releases hormones (epinephrine & norepinephrine) that release nutrients, glucose and energy.



Bringing it all together--the bits of the brain (major structures)

Use this graphic to test your knowledge of the parts of the brain we've discussed. Such as:

Is the spinal cord part of the CNS or PNS? \_\_\_\_\_

The medulla is responsible for what? and where in the brain is it?

What's the role of the choroid plexus?

The cerebellum is primarily responsible for what function?

What's in the midbrain region?

What would likely happen if the pons was damaged?

What's the role of the thalamus and what part of the brain is it in?

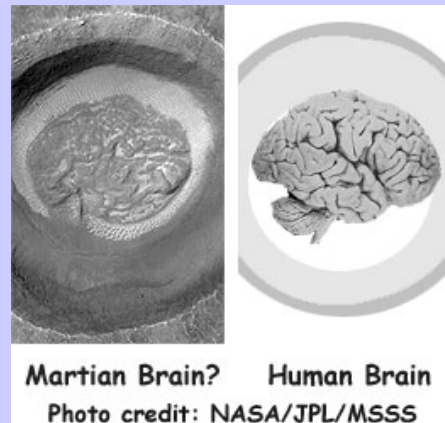
What's the corpus callosum?

What are the layers of the meninges (in the CNS from skull to brain)?

Where would you find CSF and what does it do for us?

Name a function of the pituitary gland.

## Martian Brains?



Just for fun--they found brainy looking images from Mars!

From Dr. Chudler:

I am always amazed at the photographs of distant galaxies and planets. One photograph that caught my eye recently was taken by the Mars Global Surveyor Mars Orbiter Camera and released by NASA/JPL/Malin Space Science Systems on May 5, 2004. Have a look at this picture:

<http://faculty.washington.edu/chudler/gif/martian.jpg>

Does this crater on Mars look like a human brain to you? Maybe I just see brains in strange places, but to me, this picture sure looks like a "Martian Brain" to me! For more about this photograph, see:

[http://www.msss.com/mars\\_images/moc/2004/05/05/index.html](http://www.msss.com/mars_images/moc/2004/05/05/index.html)