Lecture 14

Olfaction and The Limbic System

Objectives:

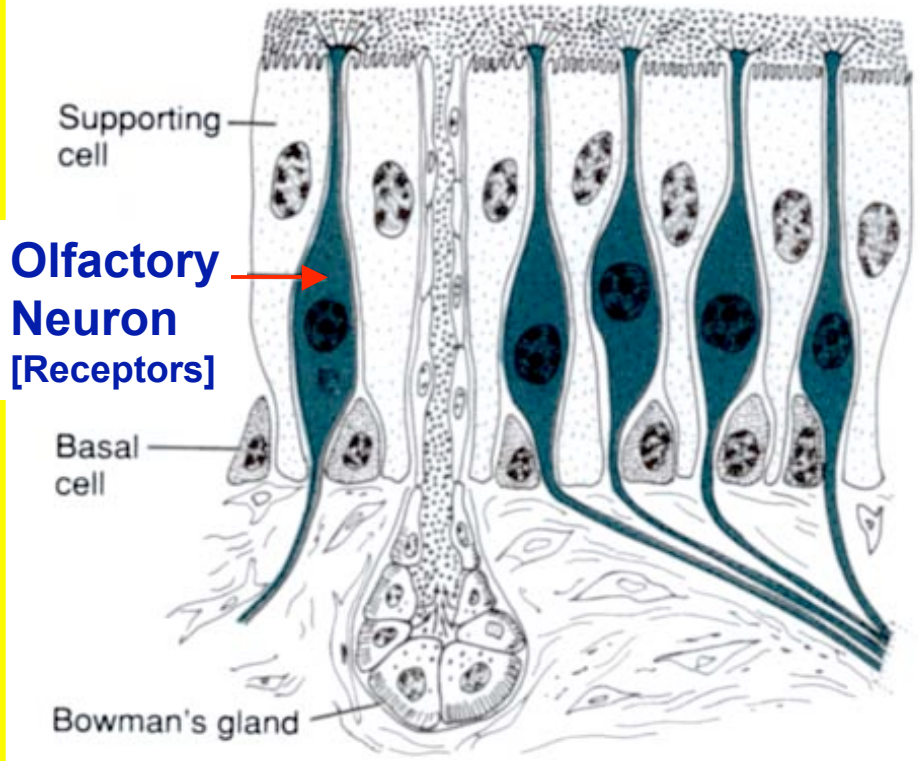
1. To understand the anatomical organization of the olfactory system
2. To understand the concept of the "limbic" system
3. To be able to identify the major components of the limbic system and associate these components with limbic system functions

Functions of the Olfactory System:

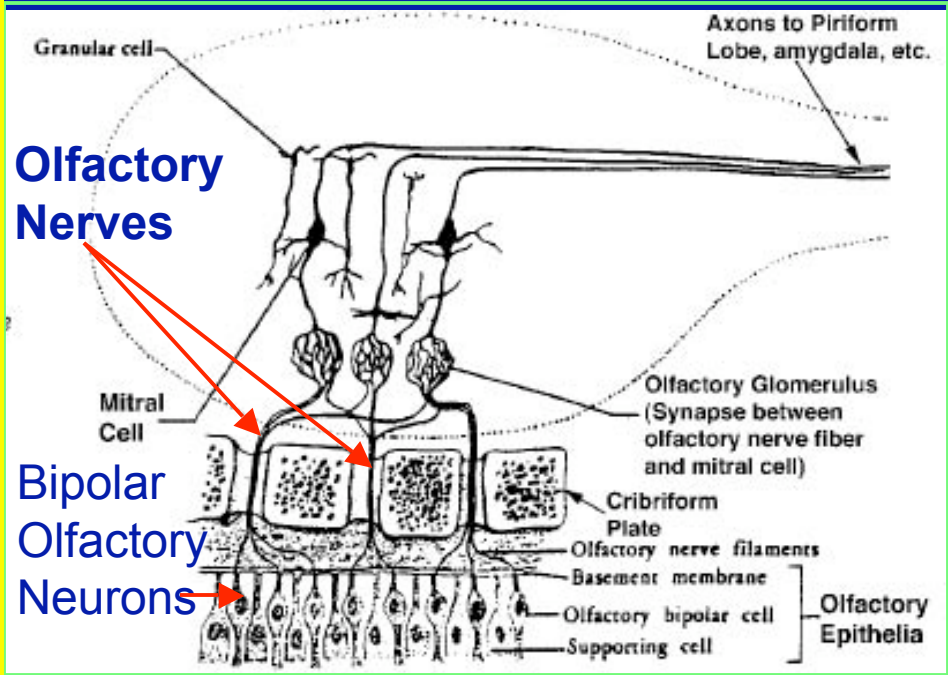
1. Identifying and finding food
2. Plays an important role in mating behavior
3. Identifying predators versus non-harmful species [bears, raccoons, owls, foxes, coyotes & mountain lions have all been known to prey on household pets]

The Olfactory System:

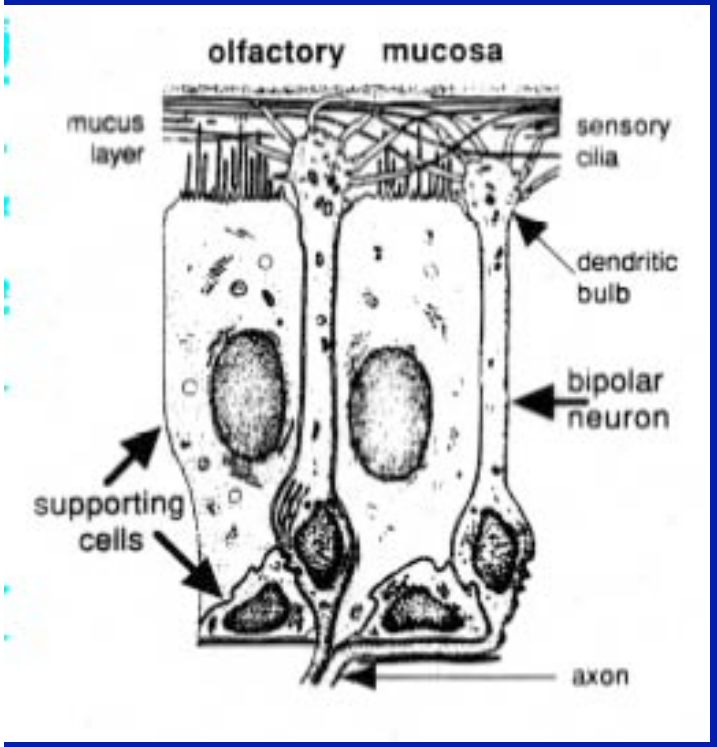
1. **Modality** — Olfaction (SVA)
2. **Receptors** — bipolar cells located in the olfactory epithelium within the upper nasal cavity.



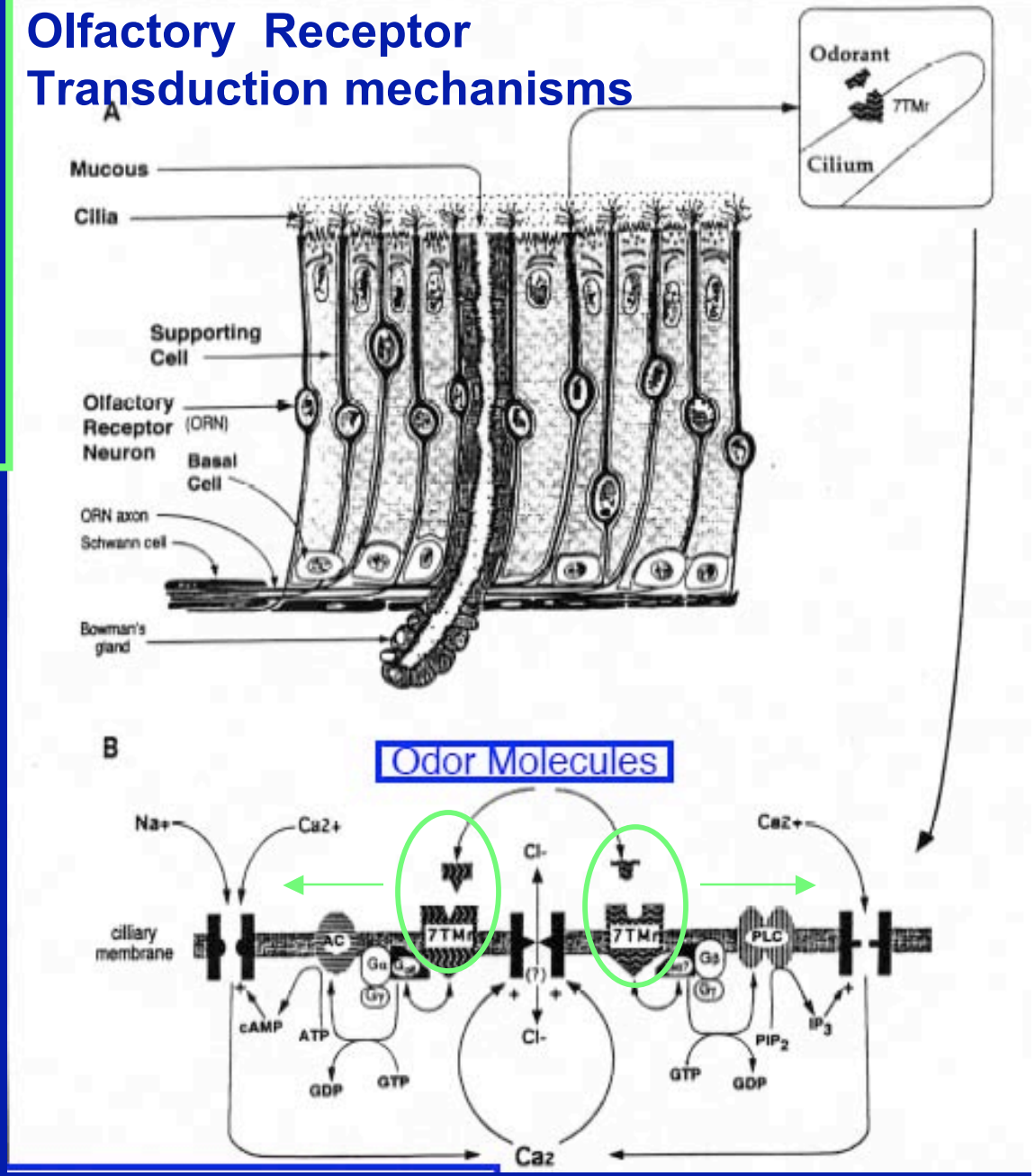
Olfactory mucosa showing 3 cell types



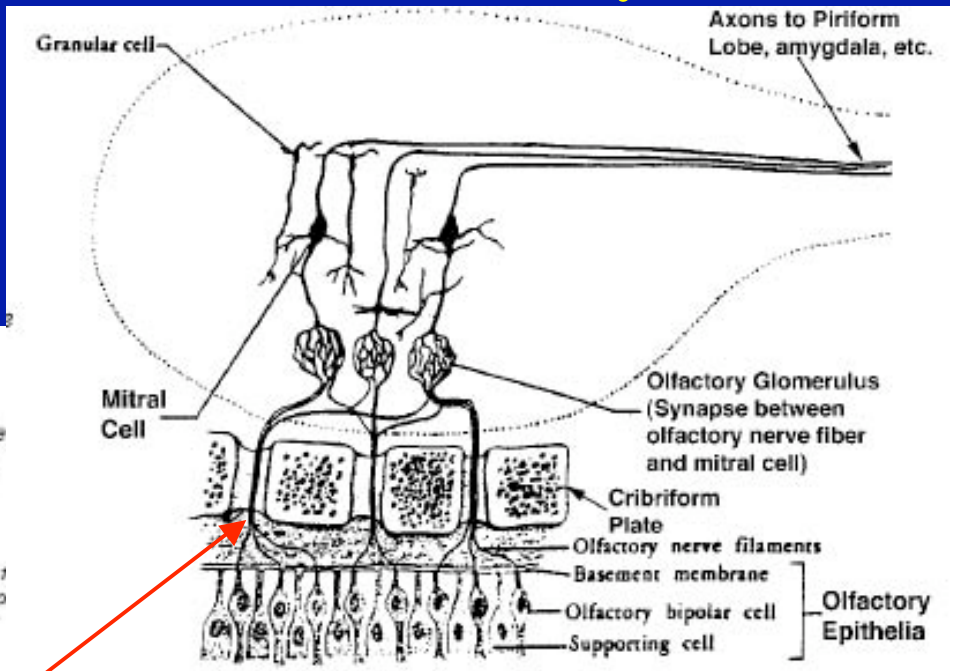
Odor molecule-->7TMr-->
G Protein-->adenylate
Cyclase-->cAMP or
phospholipase C-->
opens Ca2+ or
Na channels on cilium-->
Membrane depolarization



Olfactory Receptor Transduction mechanisms



3. First Order Neurons = receptor cells = the bipolar olfactory neurons located in the olfactory epithelium. The nonmyelinated axons of these neurons gather into bundles that collectively form the olfactory nerve. Olfactory nerve bundles penetrate the cribiform plate of the ethmoid bone to enter the olfactory bulb.



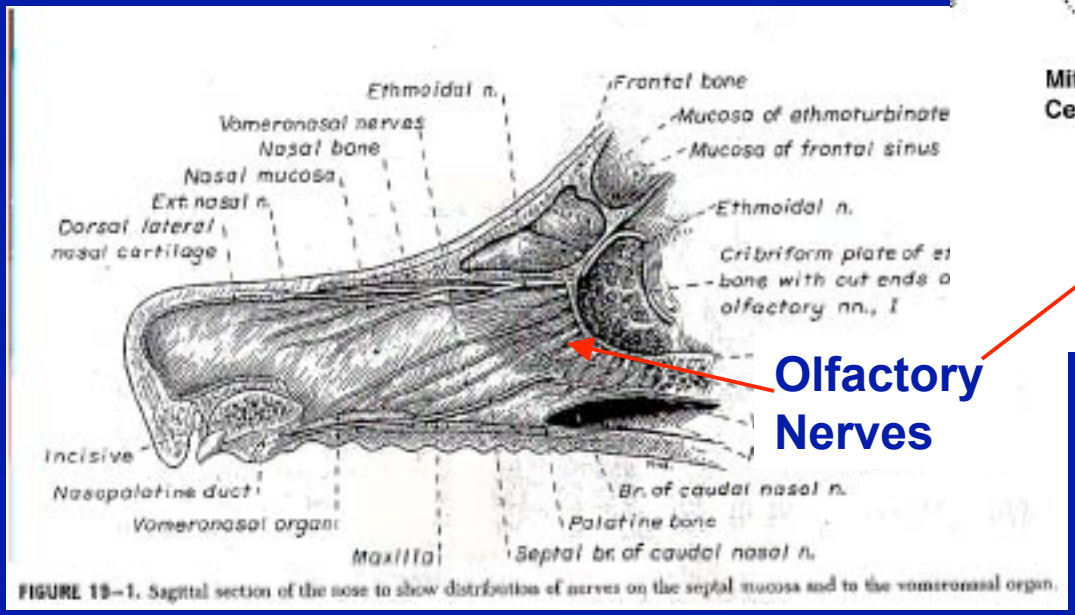
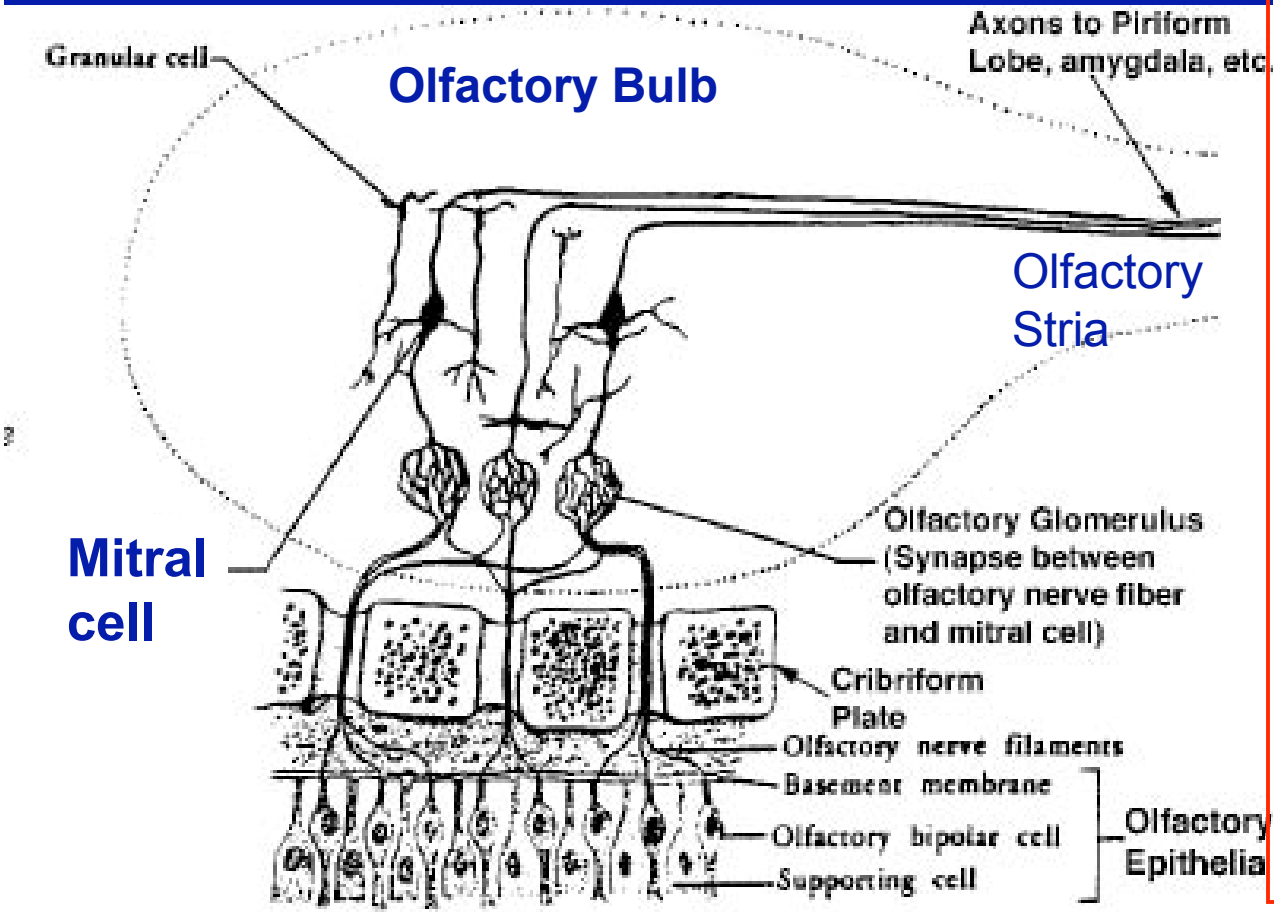


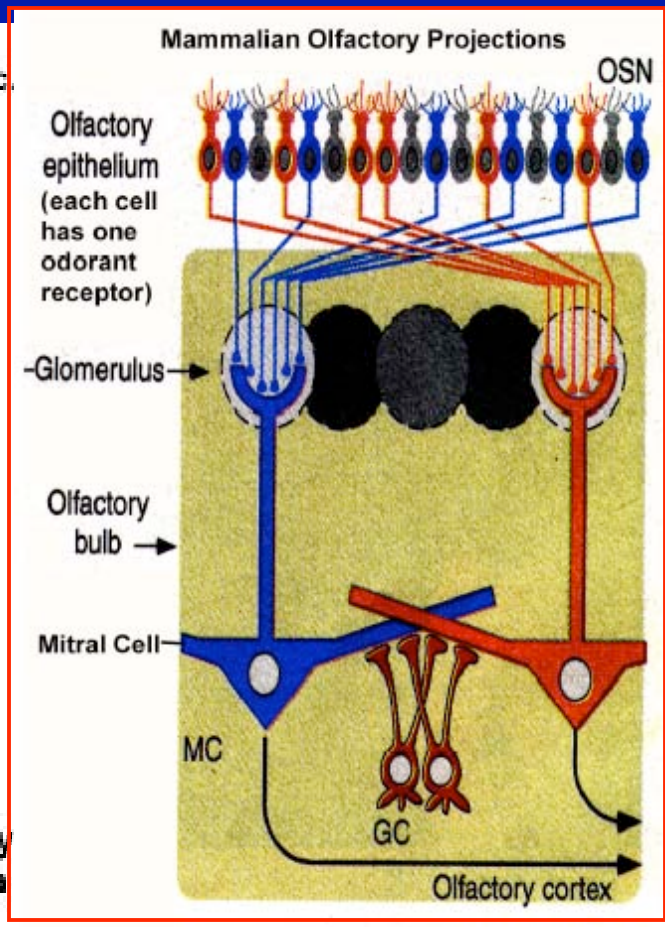
FIGURE 19–1. Sagittal section of the nose to show distribution of nerves on the septal mucosa and to the vomeronasal organ.

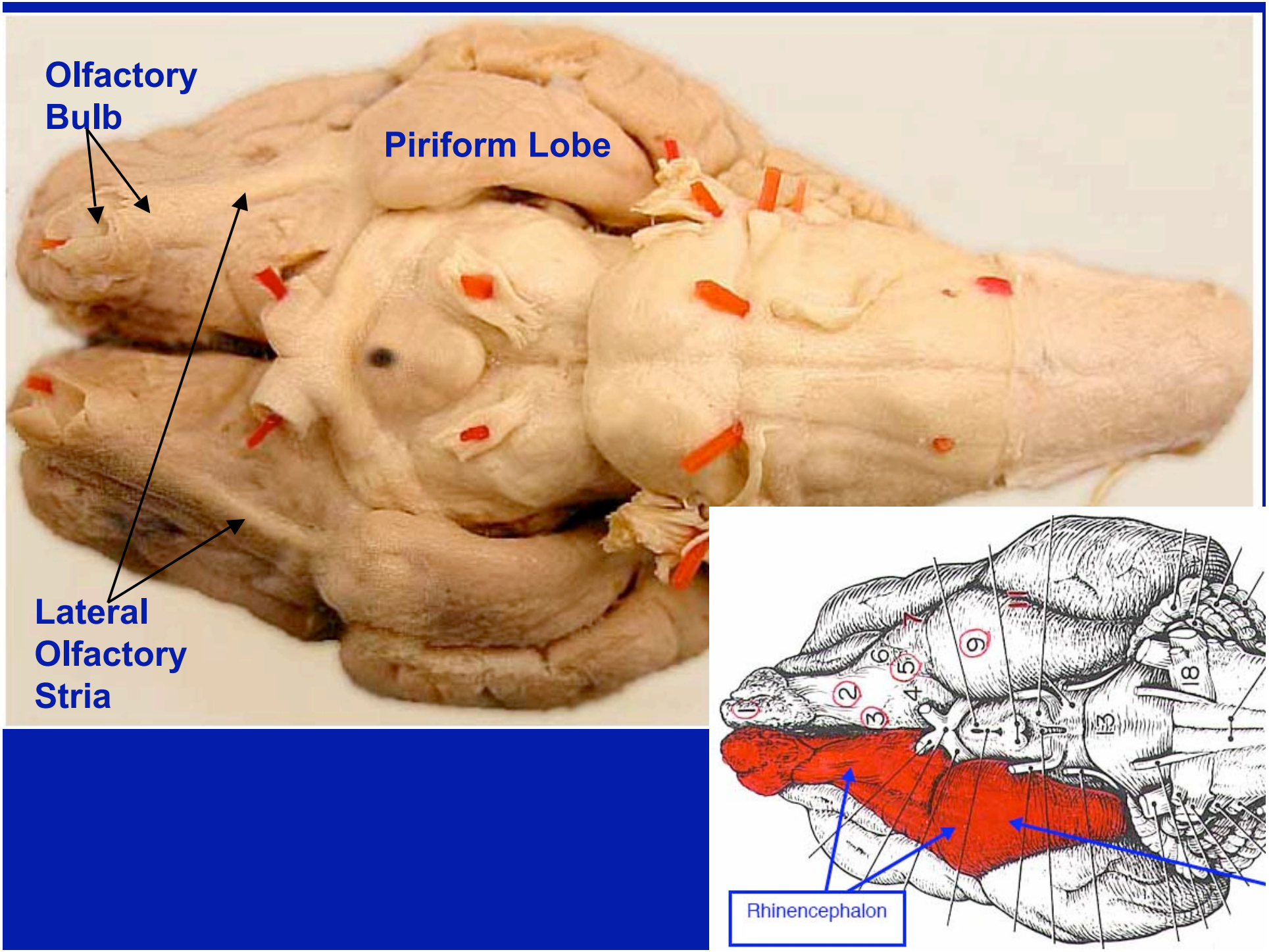
Olfactory Nerves

4. Second Order Neurons = *mitral cells* in the olfactory bulb. The axons of these cells form the olfactory tracts (striae).

5. The **olfactory tract** terminates by bifurcating into a *medial* and *lateral olfactory stria* which project, respectively, to the **septal area** (olfactovisceral reflexes) and **piriform cortex** (conscious awareness of olfaction).

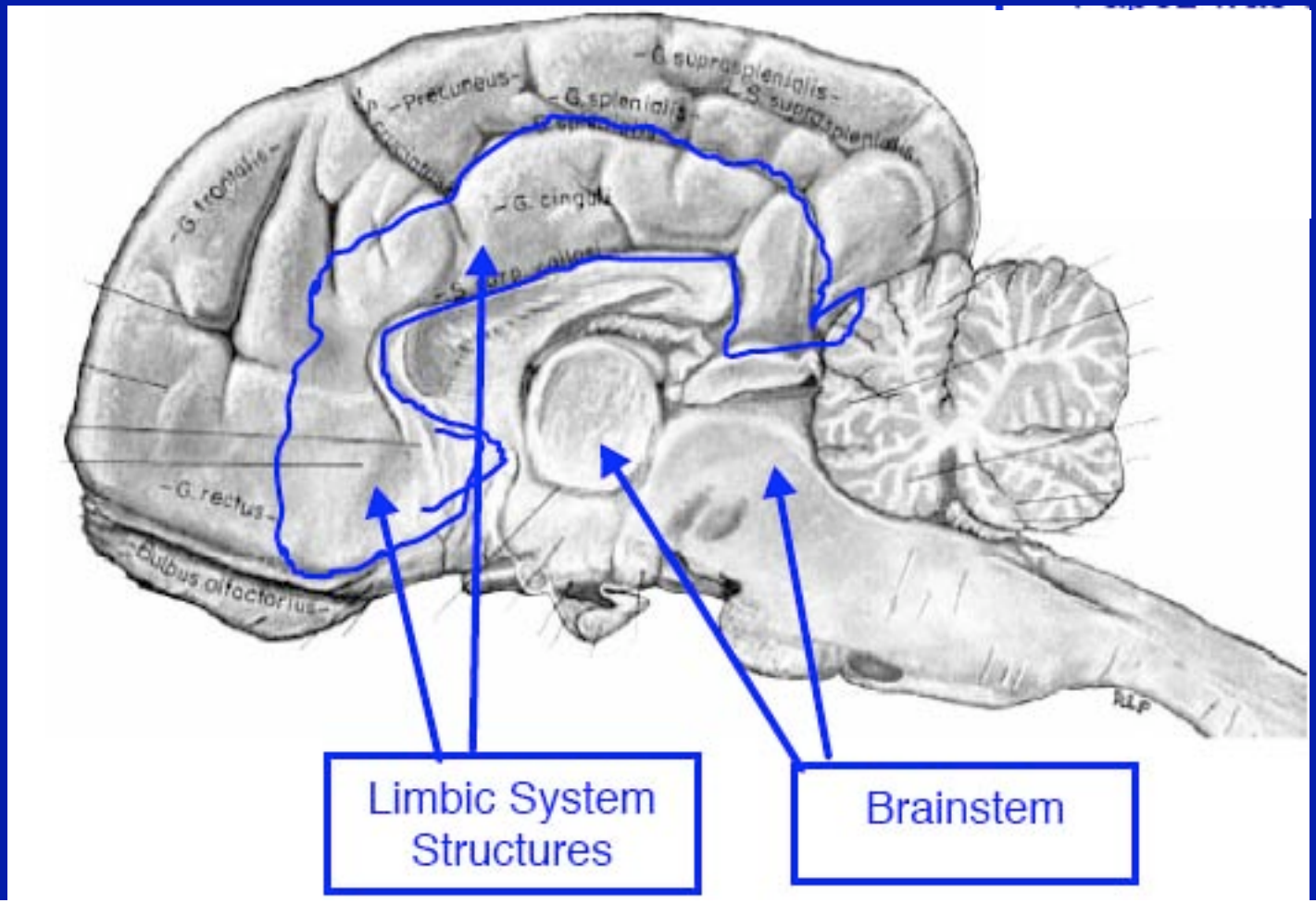





Olfactory Bulb
Piriform Lobe
Lateral Olfactory Stria
Rhinencephalon

The Limbic System: Historical Perspective

The term limbic is derived from the latin word "limbus" which means "border". Limbic refers to fact that the cortical structures which comprise the system form a border around the brainstem. James Papez suggested in 1937 that the limbic structures which surrounded the brainstem were involved in emotions.



Papez was a professor of Neurology at Cornell University. He studied the sites of lesions in dogs caused by the rabies virus

The Limbic System:

1. Functions:

In domestic animals the limbic system is concerned with

1) **emotions of importance to survival** (emotions associated with self preservation, such as escape, defense, feeding, etc.; and emotions associated with species preservation such as territorial defense, courtship, mating, etc.); and

2) processes involved in **learning and memory**.

Scene from The Amityville Horror-2005- Melissa George

Dakota Fanning
War of the Worlds

2. Criteria for being included in the limbic system:

A. **Rich innervation** by axons containing indoleamine (i.e., serotonin) and/or catecholamine (i.e., dopamine or epinephrine) neurotransmitters

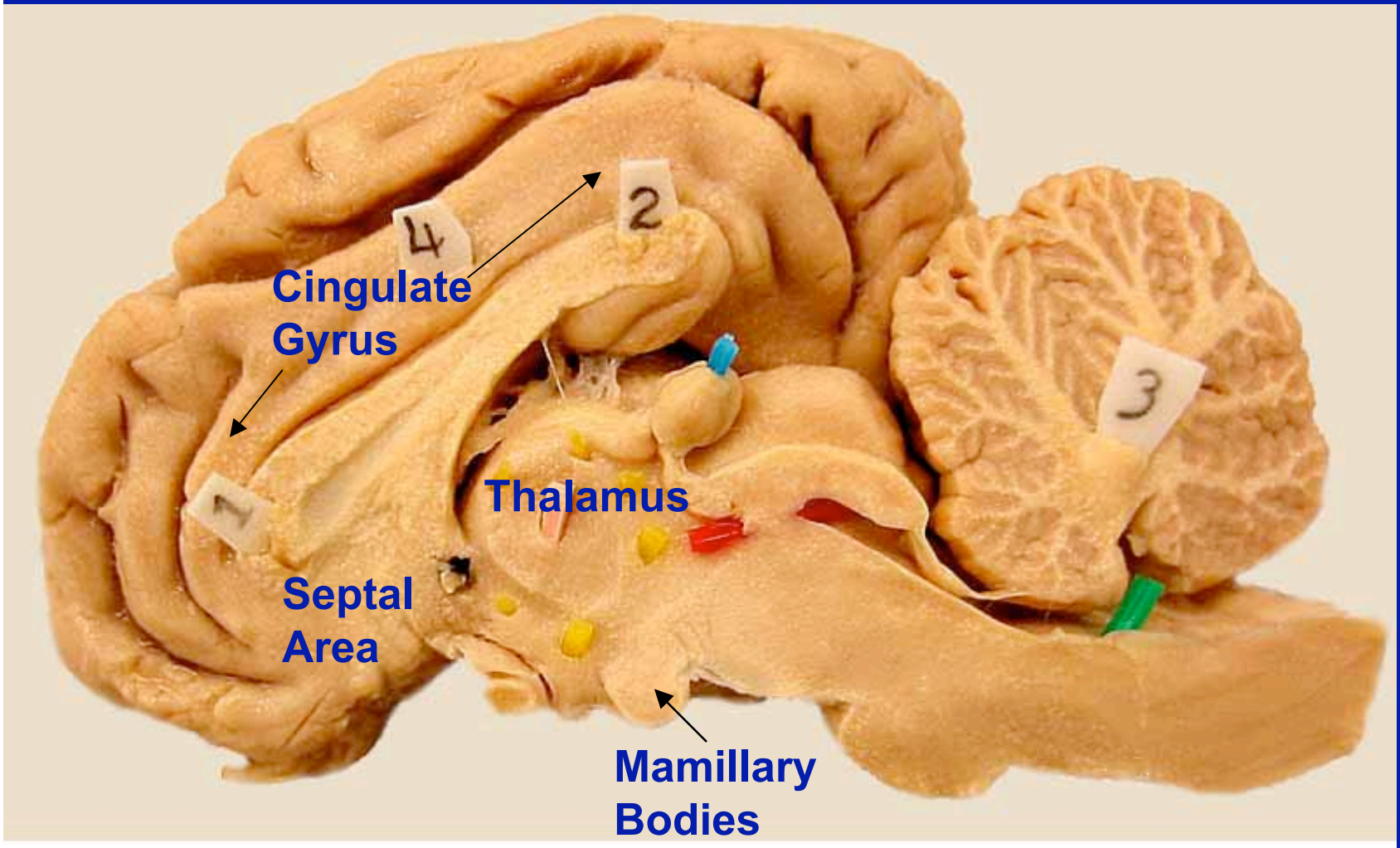
B. **Low threshold for seizure activity**; stimulation of the hippocampus or amygdala in cats induces "psychomotor" convulsions characterized by abnormal behavior (fear/rage) followed by tonic/clonic convulsions.

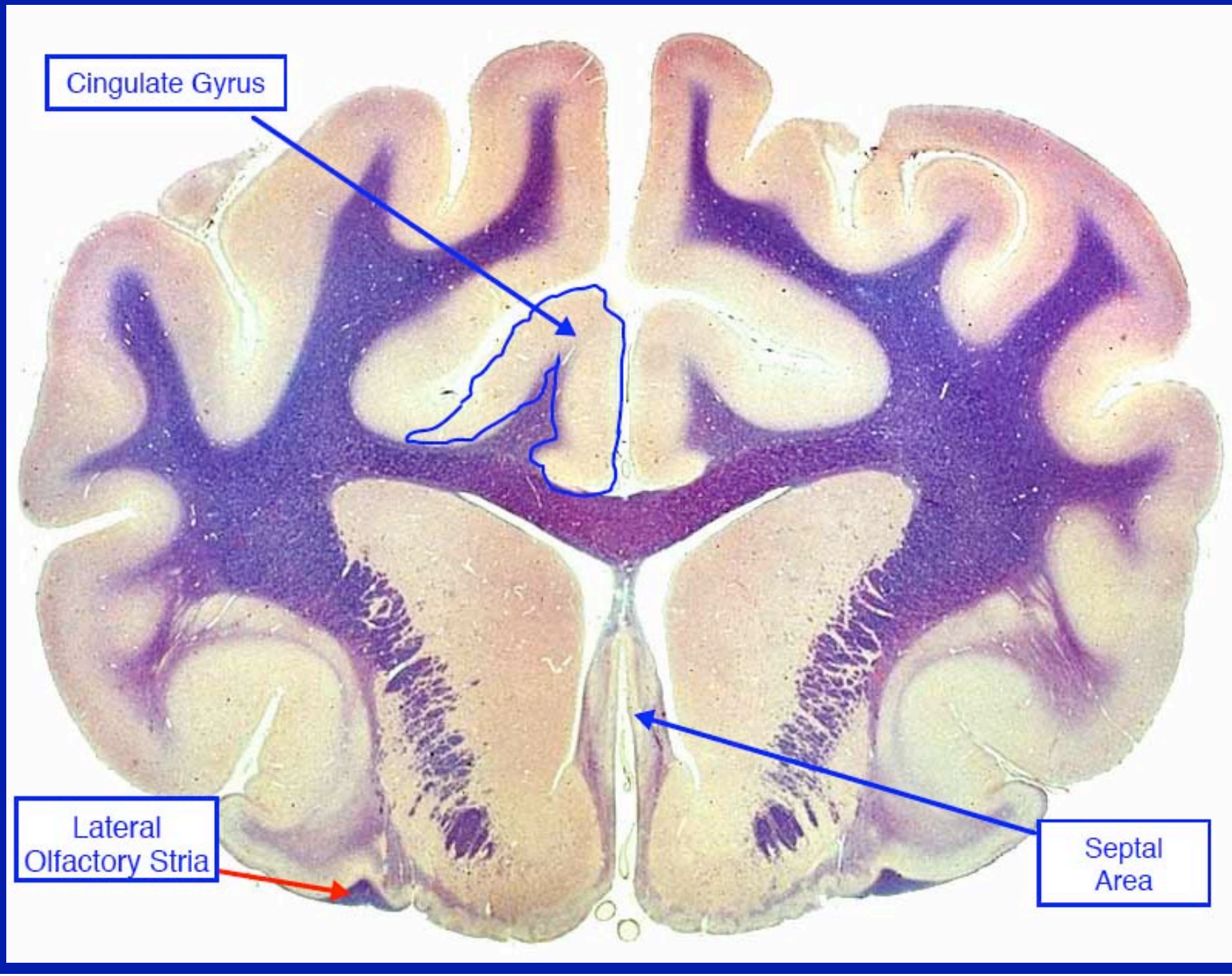
Dogs in the 1940's were fed dogfood preserved with nitrogen trichloride--> caused necrosis of the piriform lobe and hippocampus--> lead to psychomotor seizures; most common cause of psychomotor seizures today is lead poisoning

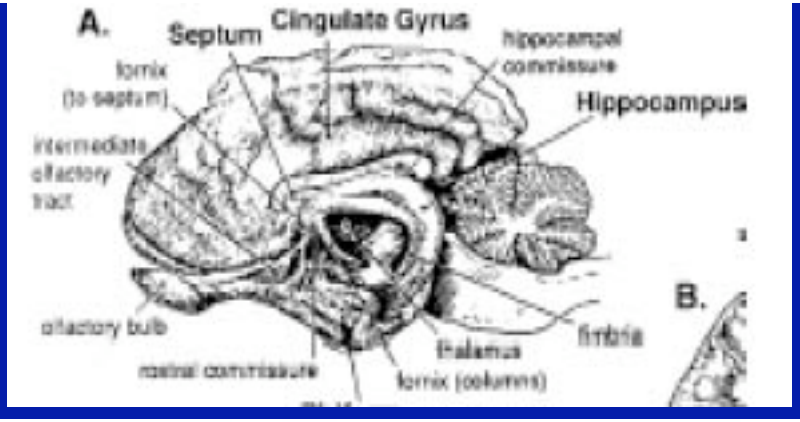
C. **Direct or indirect connections to the hypothalamus**

3. Components:

Hippocampus; Cingulate Gyrus; Amygdala; Septal Area; portions of the Thalamus; Piriform lobe; and Mammillary Bodies of the Hypothalamus




Cingulate Gyrus
Lateral Olfactory Stria
Septal Area

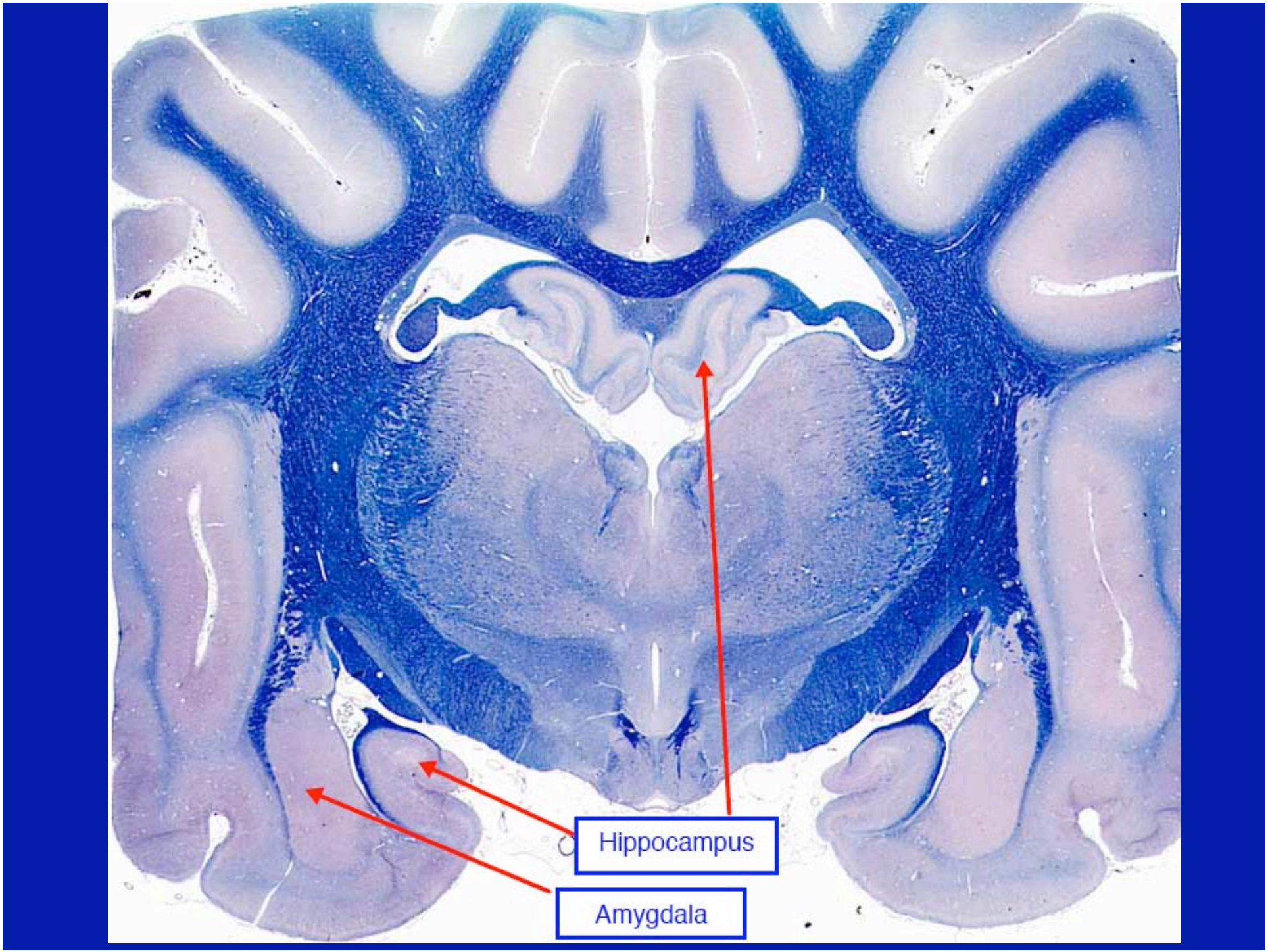


Cingulate Gyrus

Fornix

Septal Area

Hippocampus


Hippocampus
Amygdala

And Now for Something Completely Different:

Crossbred Dogs!

Malamute X Pointer = Moot Point, favorites of lawyers but…it doesn't seem to matter.

Bull Terrier X Shitzu = Bullshitz, a gregarious but unreliable breed.

Pointer X Setter = Poinsetter, a traditional Christmas Pet

Great Pyrenees X Dachshund = Pyradachs, a puzzling breed.

Pekingnese X Lhasa Apso = Peekasso, an abstract dog.

Irish Water Spaniel X English Springer Spaniel = Irish Springer, a dog fresh and clean as a whistle

Labrador Retriever X Curly Coated Retriever = Lab Coat Retriever, the choice of research scientists.

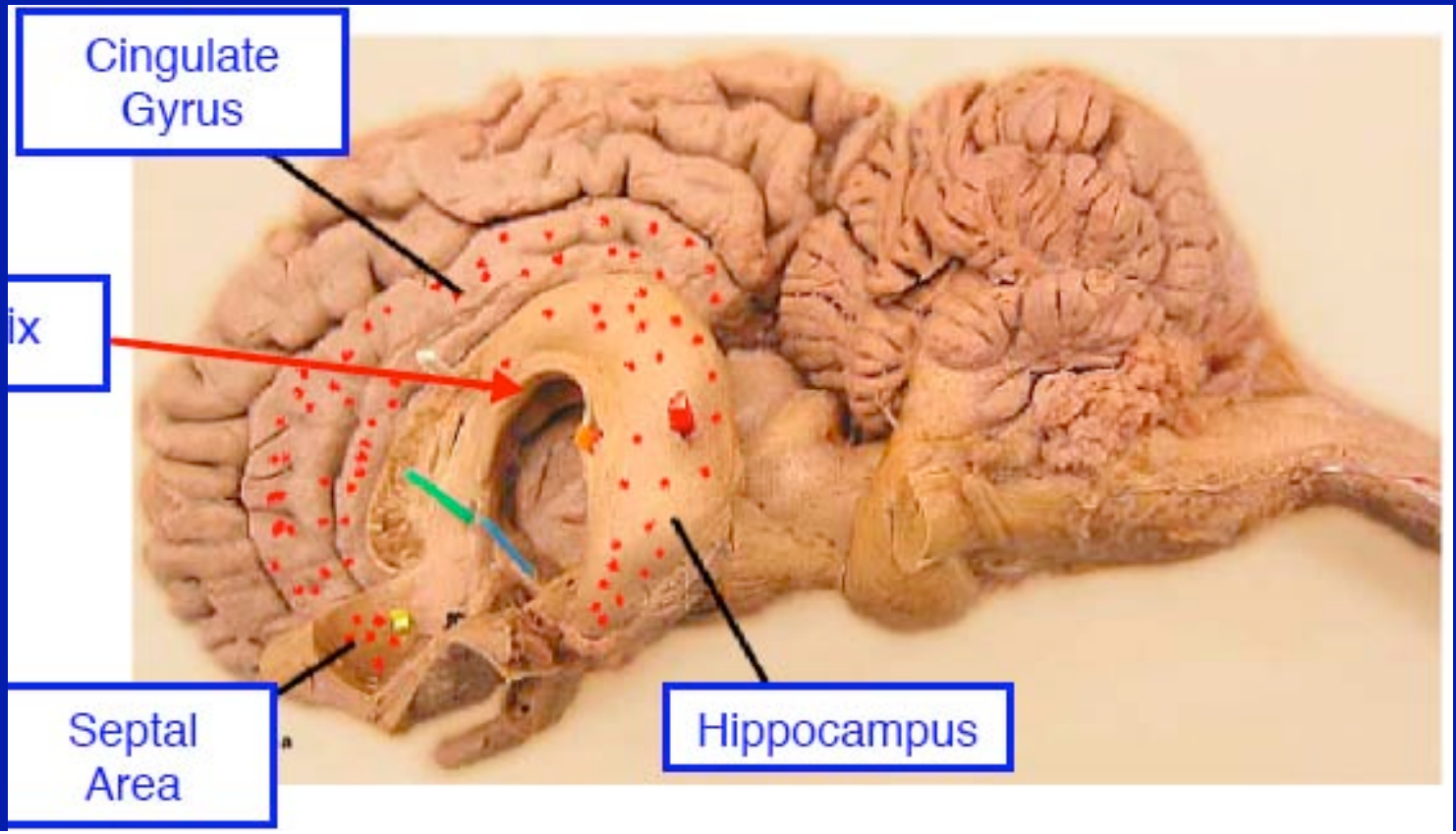
Newfoundland X Basset Hound = Newfound Asset Hound, a dog for financial advisors.

Bloodhound X Labrador = Blabador, a dog that barks incessantly.

Individual Limbic Structures and Possible Function:

In general the **neocortex has a dampening effect on emotional behavior**. This is illustrated by *sham rage*— which occurs following removal of the cerebral cortex from a cat or dog. It is characterized by: lashing of the tail, vigorous arching of the back, clawing and attempts to bite, and autonomic responses. It is called sham rage because unlike genuine rage, the anger occurs spontaneously or can be triggered by mild tactile or other non-noxious stimuli.

Hippocampus — a three layered cortical structure (archicortex) which has long been thought to be an important cortical region for associative learning and memory (particularly memory acquisition or short term memory). Both amnesia patients and animals with hippocampal damage exhibit time-dependent impairments in behavioral tasks generally described as associative or relational in nature. It is also important to note that this area of the brain has a very low seizure threshold.



Hippocampal Atrophy is one of the first signs of Alzheimer's Disease. The image below shows MRI scans of a normal and an Alzheimer's brain.

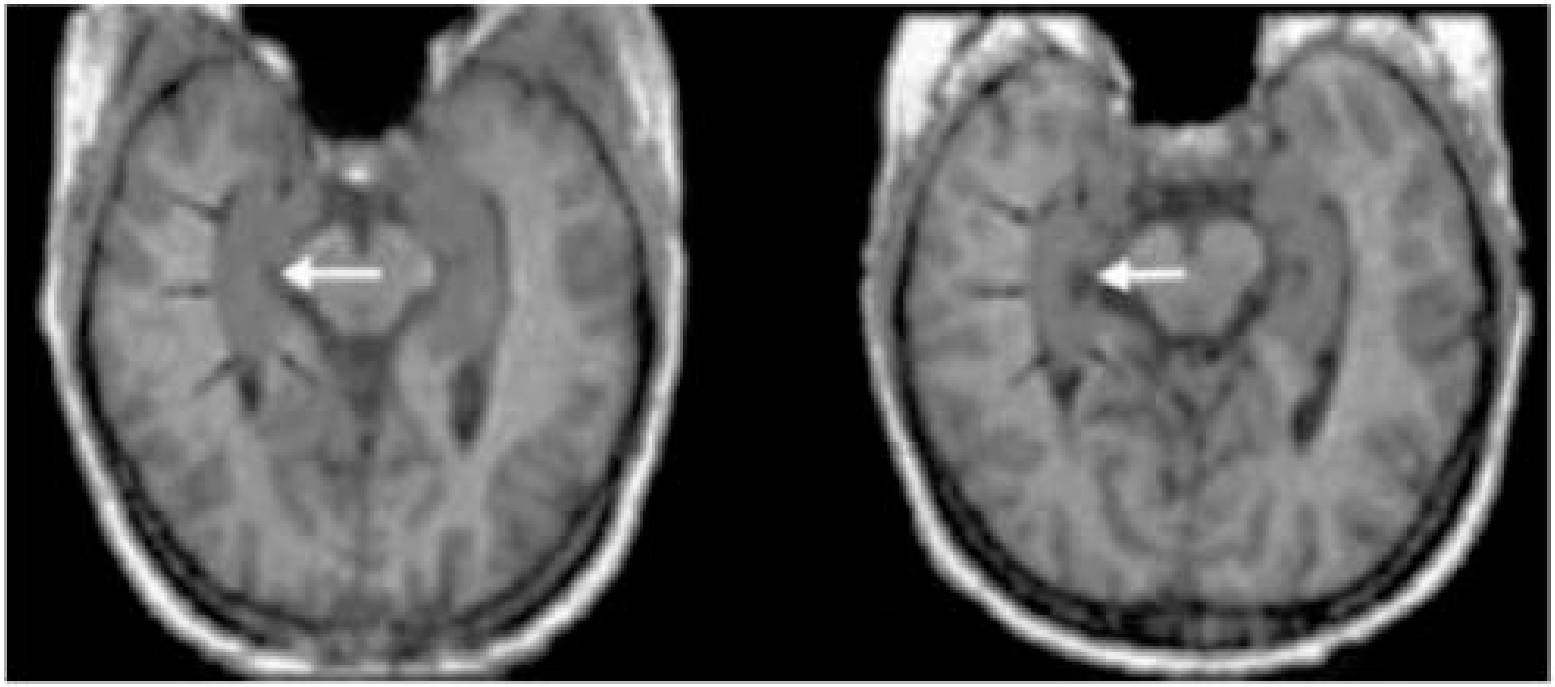
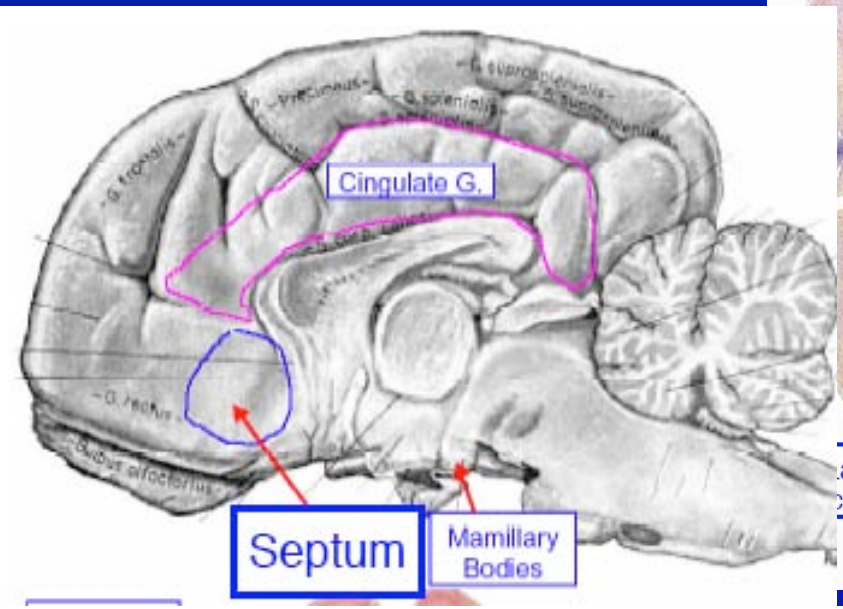
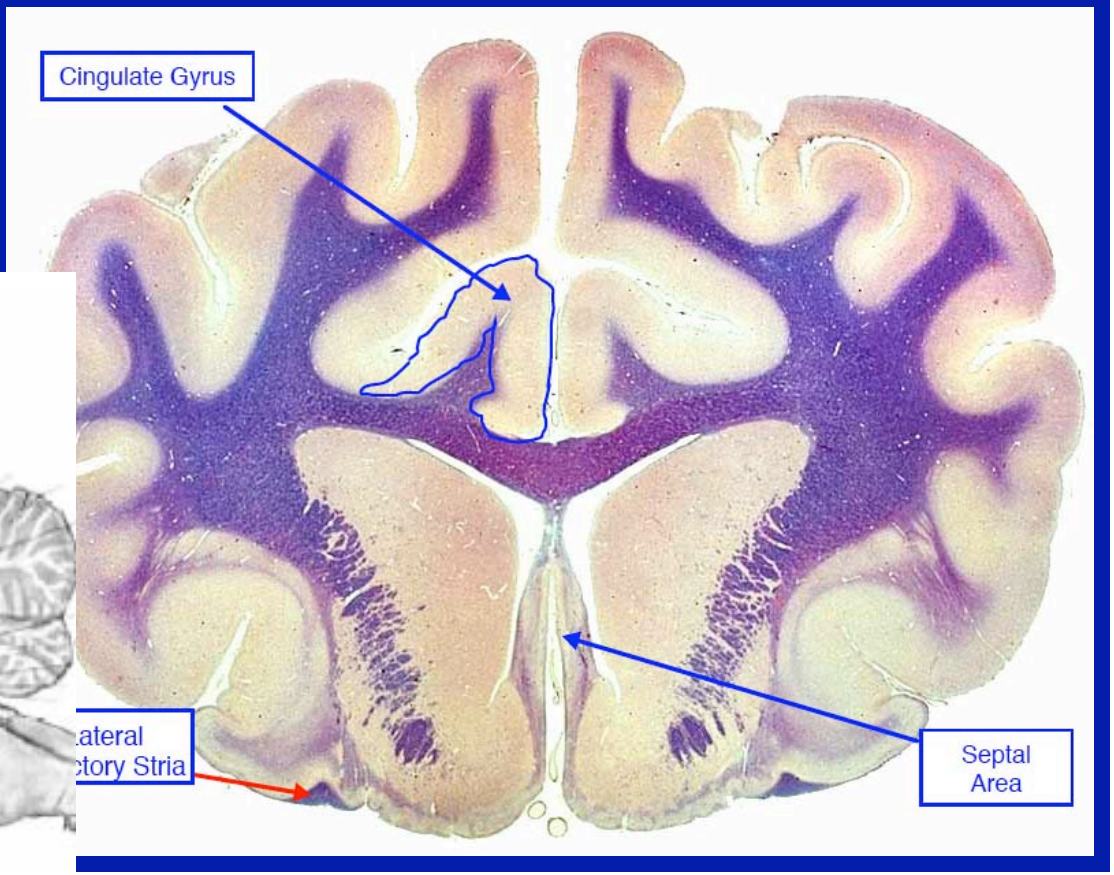


Fig. 2 Arrow highlights the body of the hippocampus. Image on right is from a patient with atrophy.

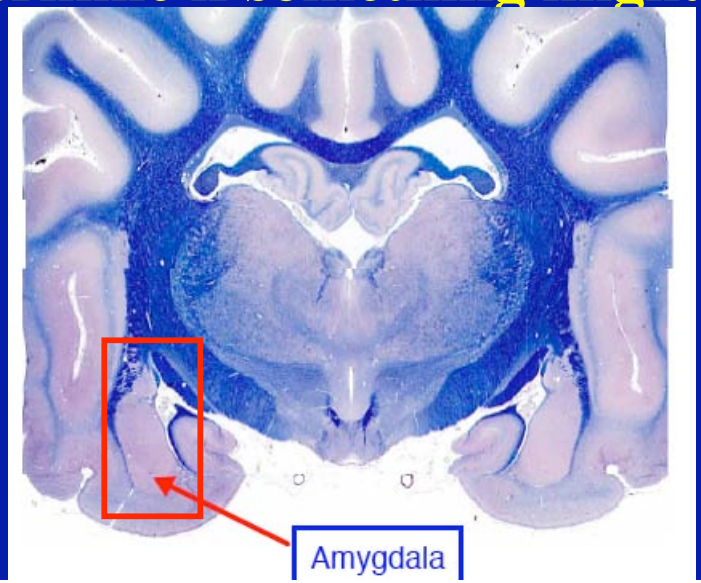
Septum — a small but conspicuous cortical area that is involved in a variety of physiological and behavioral processes including emotions, relief of fear, docile behavior and stress, as well as, a role in autonomic regulation (e.g., water/food intake, hibernation, etc.). It is a very ancient structure. *Stimulation* induces docile behavior and can suppress many autonomic responses [animals with electodes in septal area will bar press; Pleasure Area]. *Lesions* result in rage and aggressive behavior and can trigger many autonomic responses.





Amygdala — a highly differentiated region near the temporal pole of the mammalian cerebral hemispere. It is a basal nucleus that is implicated in a bewildering variety of behavioral and regulatory functions. These include emotion and memory, social behaviors such as reproduction, fear and aggression, and modulation of the autonomic and neuroendocrine systems. Many amgdala effects appear opposite to those of the septum. For instance, *lesions* result in docile behavior, while *stimulation* produces rage and aggressive behavior.

Has ability to discern and express even subtle social-emotional nuances such as friendliness, fear, affection, distrust, anger, etc., and at a more basic level, determine if something might be good to eat.



Hypothalamus —The hypothalamus is the central core from which all emotions derive their motive force.
Because of its interconnections with other limbic structures, simulation of the hypothalamus produces many of the behaviors seen with stimulation of other limbic sites. Thus stimulation reveals rage and aggression sites as well as sites that produce cowering or docile behavior.

Thalamus — links the limbic system to the neocortex and provides a means by which sensory information can gain access to the limbic system.

Rhinencephalon (nose-brain) **—** includes the piriform lobe and olfactory bulb. It is concerned with olfaction and is a major component of the limbic system where it functions together with other limbic structures in affective behavior (urges, behavioral drives).

Behavioral abnormalities are common in domestic animals and include in:

1. Normal habits
2. Personality
3. Attitude
4. Reaction to the environment

Clinical Signs Associated with Damage to Limbic Structures Include:

1. Dullness
2. Lethargy
3. Sleepiness
4. Stupor or semicoma
5. Dementia
6. Failure to recognize owners or familiar environment
7. Inability to learn
8. Destructive behavior
9. Irritability or aggressiveness
10. Propulsive pacing or circling