Introduction to Systems Neuroscience

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The limbic system

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http: www.ini.unizh.ch/~kiper/system_neurosci.html

LIMBIC SYSTEM

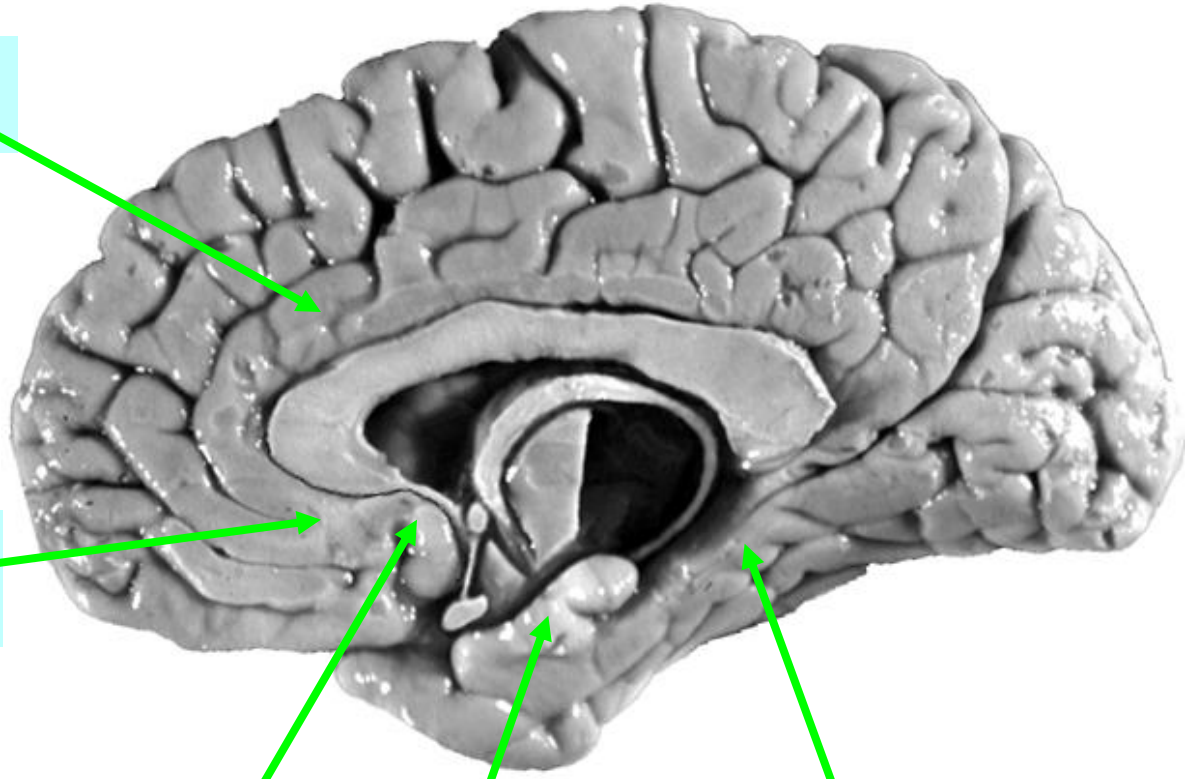
The term *limbic system* mean the entire neuronal circuitry that controls *emotional behavior and motivational drives.*

What is the Limbic System?

Anatomically speaking:

- Hypothalamus
- Limbic lobe
- Hippocampus
- Amygdala

Limbic lobe:
C-shape border of hemisphere



A major part of the limbic system is the hypothalamus with its related structures.

hypothalamus is a collection of nuclei

They control:

- **emotional behavior**
- **internal conditions of the body such as *temperature*, *osmolality of the body fluids,* and *drives to eat and drink*, and *to control body weight***

These are collectively called *Vegetative Functions of the brain*

Functional Anatomy of the Limbic System : Key Position of the Hypothalamus

lec: dont learn all this by heart

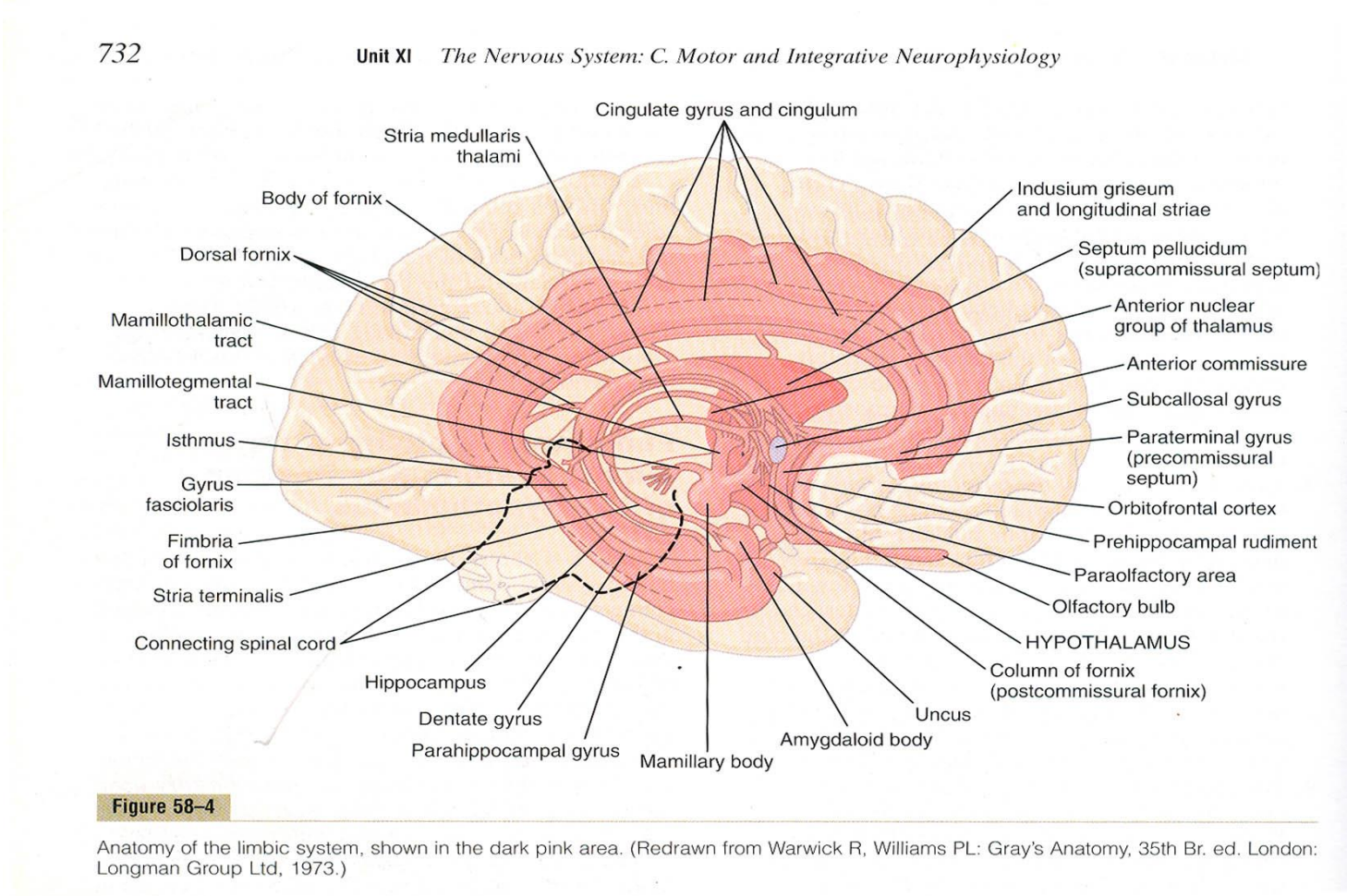


Figure 58–4

Anatomy of the limbic system, shown in the dark pink area. (Redrawn from Warwick R, Williams PL: Gray's Anatomy, 35th Br. ed. London: Longman Group Ltd, 1973.)

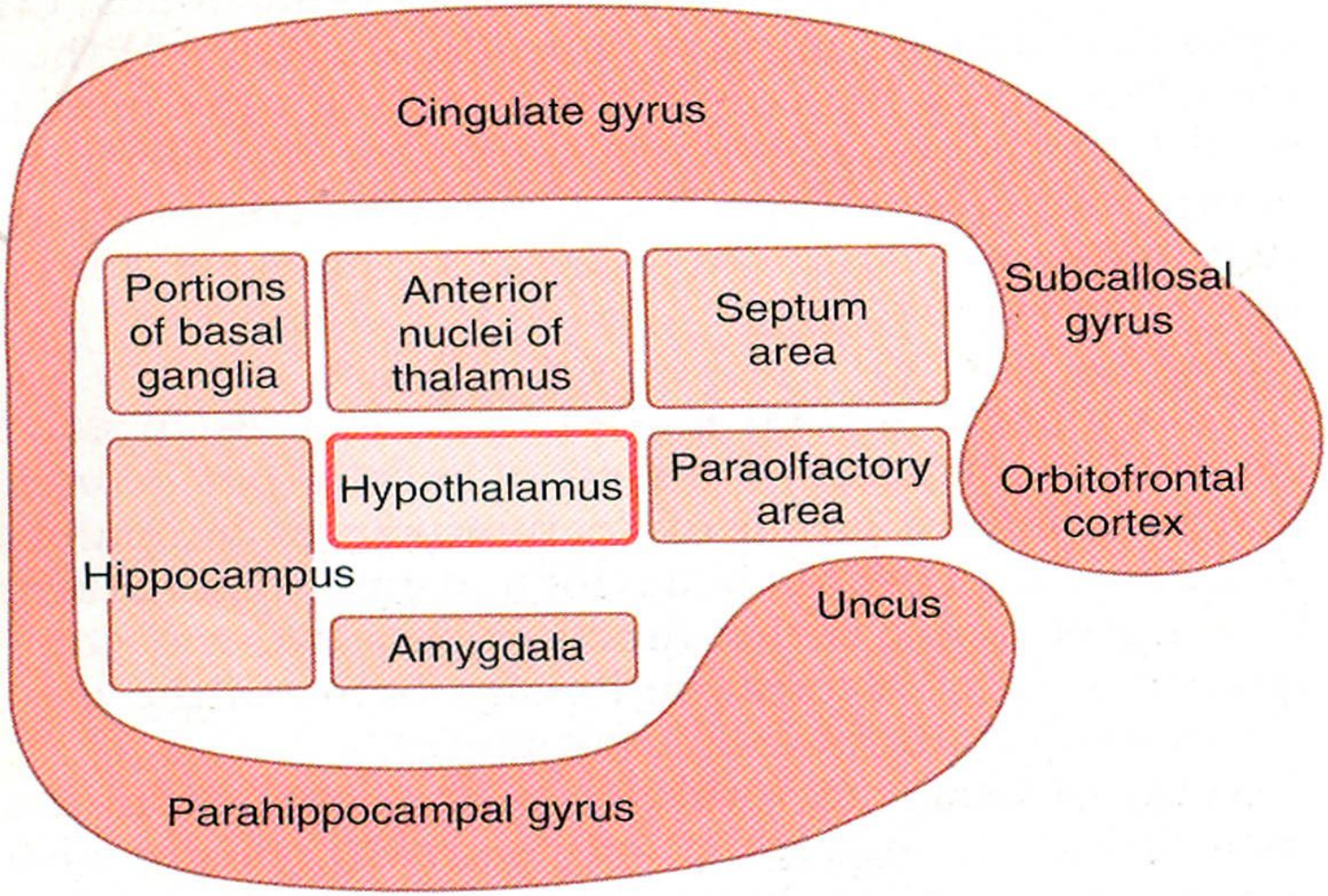


Figure 58–5

Limbic system, showing the key position of the hypothalamus.

Hypothalamus, a Major Control Headquarters for the Limbic System

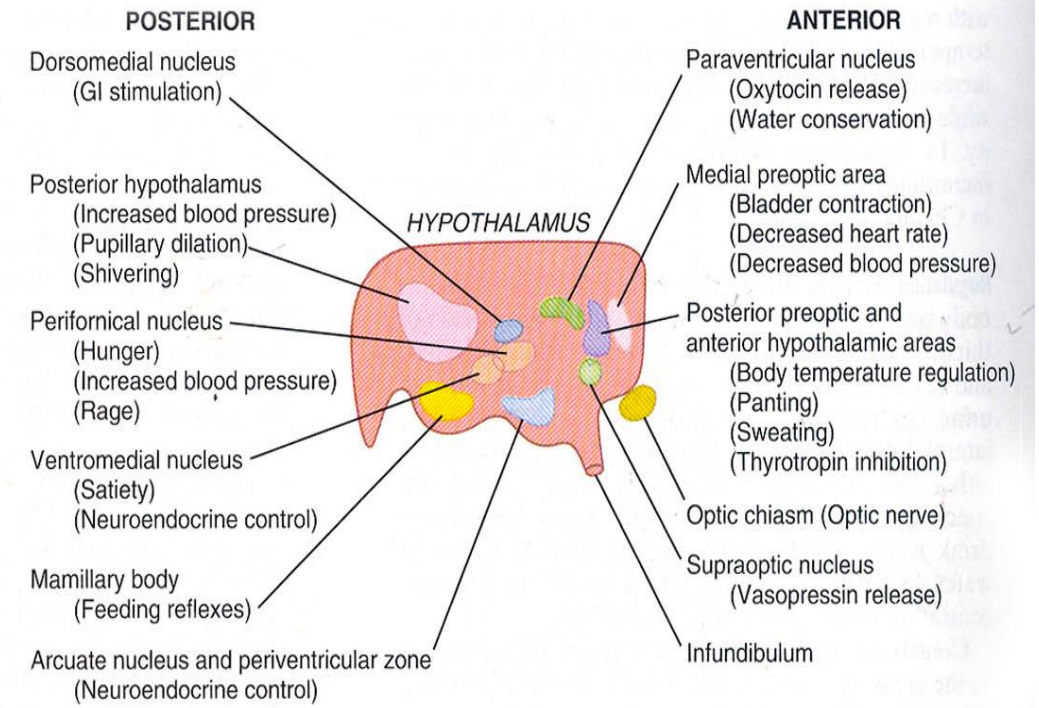


Figure 58–6

Control centers of the hypothalamus (sagittal view).

Hypothalamus represents less than 1% of the brain mass. It is one of the most important of the control pathways of the limbic system.

It controls most of the **Vegetative and Endocrine functions** of the body as well as many aspects of **Emotional Behavior**

A. Vegetative and Endocrine Control Functions of the Hypothalamus

- **Cardiovascular Regulation**
- **Regulation of body Temperature**
- **Regulation of Body Water**
- **Regulation of Uterine Contractility and of Milk Ejection from the Breasts**
- **Gastrointestinal and Feeding Regulation**

1. stimulation of the lateral hypothalamic area results to extreme hunger, voracious appetite and intense desire for food

2. damage this area causes lose of desire for food, causing lethal starvation

<u>Hypothalamic</u> control of Endocrine Hormone Secretion by the Anterior Pituitary Gland

Behavioral Functions of the Hypothalamus and Associated Limbic Structures

*** Effects Caused by Stimulation ***

- ✓ **Stimulation of the *lateral hypothalamus* causes *thirst and eating*, *increased general level of activity, leading to overt rage and fighting***
- ✓ **Stimulation of the *ventromedial nucleus* causes sense of *satiety, decreased eating* and *tranquility***
- ✓ **Stimulation of a *thin zone of periventricular nuclei,* leads to *fear* and *punishment reactions***
- ✓ **Sexual drive can be stimulated from several areas of the hypothalamus especially the anterior and most of the posterior portions of the hypothalamus**

Effects Caused by Hypothalamic Lesions –

Cause effects opposite to those caused by stimulation.

“Reward” and “Punishment” Function of the Limbic System

The limbic structures are concerned with the a*ffective* nature of sensory sensations – that is, whether the sensations are *pleasant* or *unpleasant* or also called *reward* or *punishment* or *satisfaction* or *aversion*

Reward Centers

human self stimulation: same subject on some days would report euphoria, on other days, neutral or depressive feelings

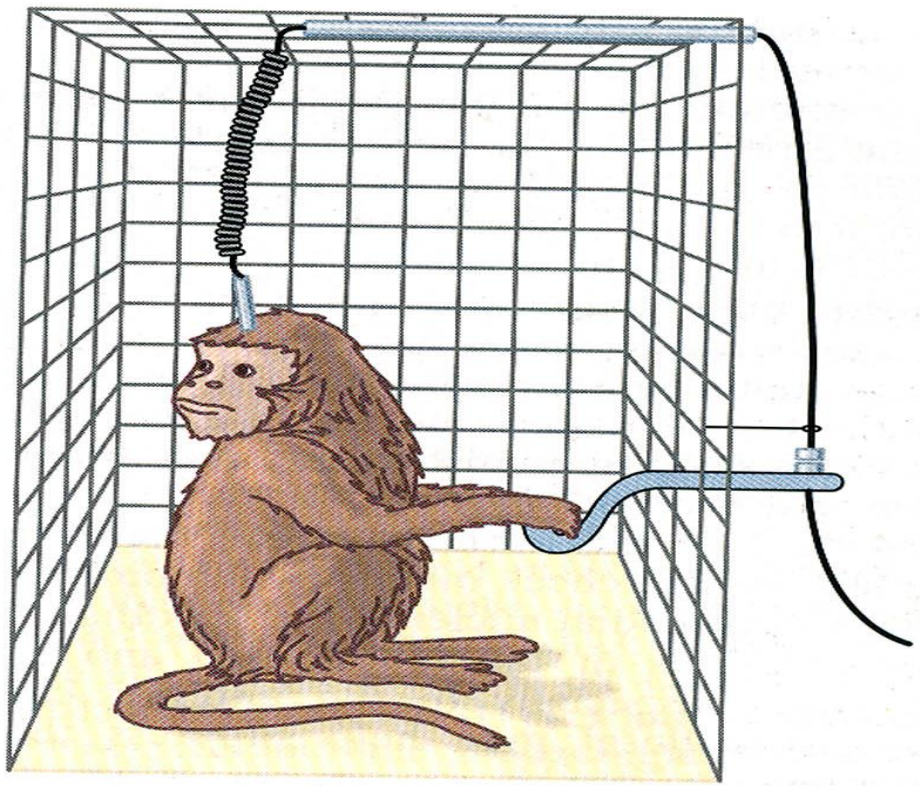


Figure 58–8

Technique for localizing reward and punishment centers in the brain of a monkey.

- The major reward centers are located *along the course of the medial forebrain bundle,* especially in the *lateral* and *ventromedial nuclei of the hypothalamus*

  weaker stimuli gives a sense of reward, and stronger ones a sense of punishment

- Less potent reward centers – septum, amygdala, certain areas of the thalamus and basal ganglia

  basal ganglia: motor control etc, shoiuld not really be included in the limbic system

Stimulation of these areas gives a sense of *reward.* When offered the choice of eating some delectable food, the animal often chooses the electrical stimulation

Punishment Centers

- Most potent areas have been found in the central gray area surrounding the aqueduct of Sylvius in the mesencephalon
- Less potent punishment areas are found in the amygdala and hippocampus

Stimulation in these areas causes the animal to show all **signs of displeasure**, ***fear, terror, pain and even sickness.***

Rage – Its Association with Punishment Centers

Strong stimulation of the punishment centers, especially in the periventricular zone of the hypothalamus and the lateral hypothalamus causes the animal to:

1. develop a defense posture
2. extend its claws
3. lifts its tail
4. hiss
5. spit
6. growl
7. develop piloerection, wide-open eyes and dilated pupils

- **Placidity and Tameness**

Exactly the opposite emotional behavior patterns occur when the reward centers are stimulated

Importance of Reward or Punishment in Behavior

Almost everything that we do is related to reward and punishment. If we are doing something rewarding, we continue to do it; if it is punishing we cease to do it.

Reward and punishment centers constitute one of the most important of all the controllers of our bodily activities , our drives, our aversions, our motivations

Importance of Reward or Punishment in Learning and Memory – Habituation Versus Reinforcement

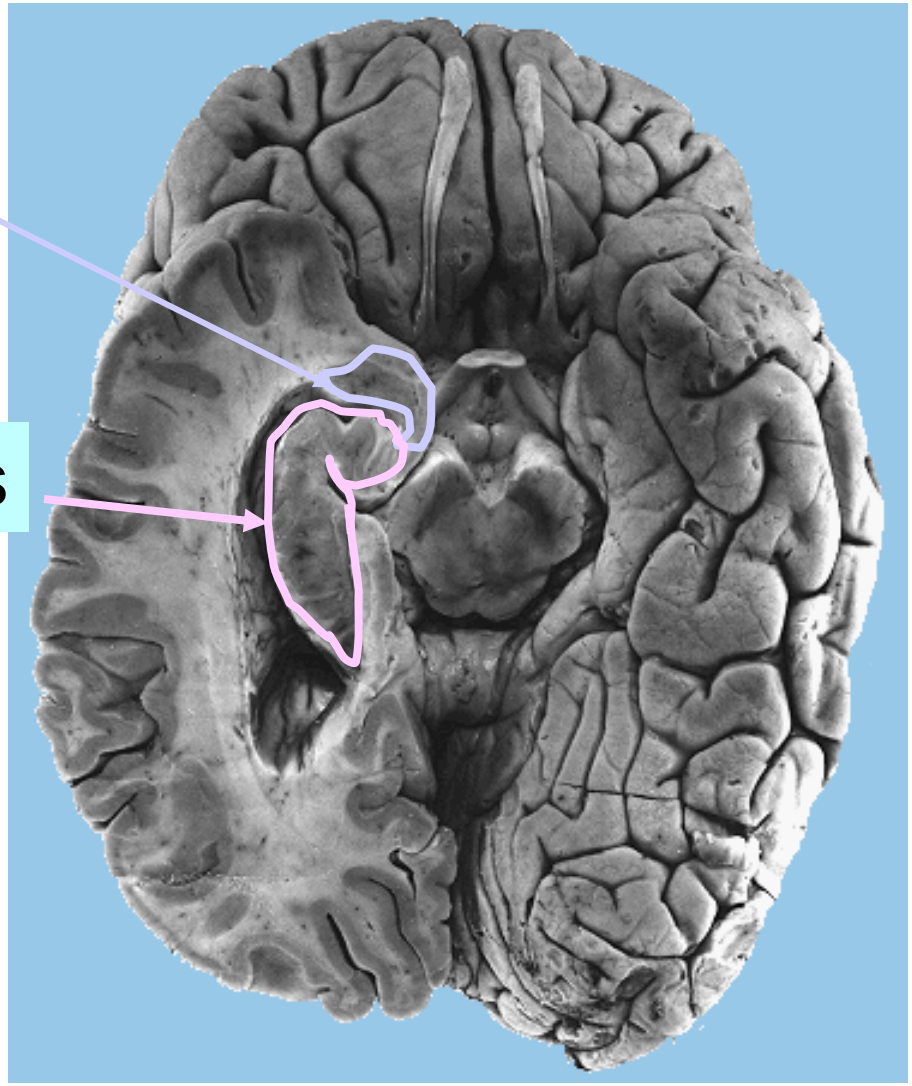
If the sensory experience does not elicit a sense of either reward or punishment, repetition of the stimulus over and over leads to almost complete extinction of the cerebral cortical response, thus the animal becomes habituated to that specific sensory stimulus and thereafter *ignores* it.

If the stimulus does cause either reward or punishment , the cerebral cortical response becomes progressively more and more intense during repeated stimulation and the response is said to be *reinforced.*

Medial temporal lobe: hippocampus and amygdala

amygdala

hippocampus



hippocampus is anatomically spoken cortex structure (not neocortex)
the amygdala is not. it has subcortical structure

Specific Functions of Other Parts of the Limbic System

Role of the Hippocampus in Learning

Effect of bilateral Removal of the Hippocampi – Inability to Learn

Theoretical Function of the Hippocampus in Learning- Without the hippocampi, *consolidation* of long-term memories of verbal or symbolic thinking type is poor or does not take place.

Hippocampus:

- vulnerable to damage from anoxia, stress, environmental toxins
- often is epileptogenic focus

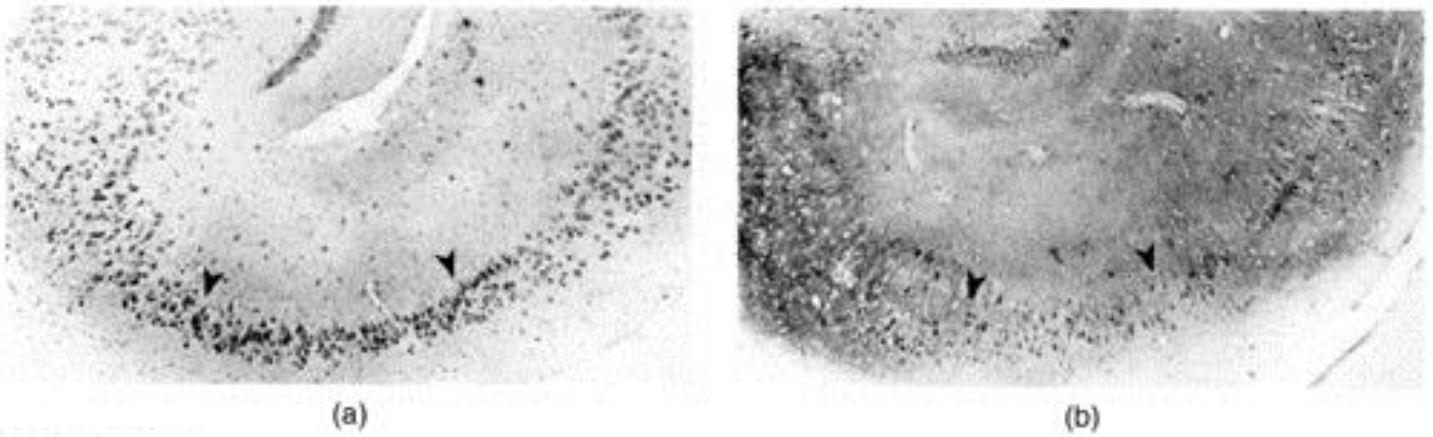


FIGURE 16.6

Photomicrographs showing brain damage caused by stress. (a) Section through the hippocampus of a normal monkey. (b) Section through the hippocampus of a monkey of low social status subjected to stress. Compare the regions between the arrowheads, normally filled with large pyramidal cells.

(From Uno, H., Tarara, R., Else, J. G., Suleman, M. A., and Sapolsky, R. M. Journal of Neuroscience, *1989,* 9, *1706–1711. Reprinted by permission of the* Journal of Neuroscience.*)*

HM: bilateral removal of hippocampus

- Unable to lay down new declarative memories
- Old memories intact
- No change in intellect
- No problems with procedural memory

Amygdala

Receives neuronal signals from all portions of the limbic cortex.

Because of its multiple connection, it is called the *"Window"* through which the limbic system sees the place in the word

typo: World

Amygdala: function and connections

- Highly processed sensory input
- Widespread outputs to cortex, hippocampus, hypothalamus, brainstem
- Responsible for learning and maintenance of link between a stimulus and its emotional value.
- Stimulation - fear and anxiety, deja vu
- Lesion – e.g. Kluver-Bucy syndrome

Effects of Bilateral Removal of the Amygdala - ***Kluver-Bucy Syndrome***

- Placid, flat affect contents are not associated to emotional content anymore
- Fearless
- Inappropriate social and sexual behavior

explore world by putting stuff in mouth

- Hyperoral and overly curious

*Amygdala: learning and memory of emotional significance of stimuli

Overall Function of the Amygdala

It is the behavioral awareness areas that operate at a semiconscious level.

The amygdala is believed to make the person's behavioral response appropriate for each occasion

(next few slides are summary slides)

Functional roles

- Hippocampus:

  learning and declarative memory

  – memory for facts, events, faces, places etc.

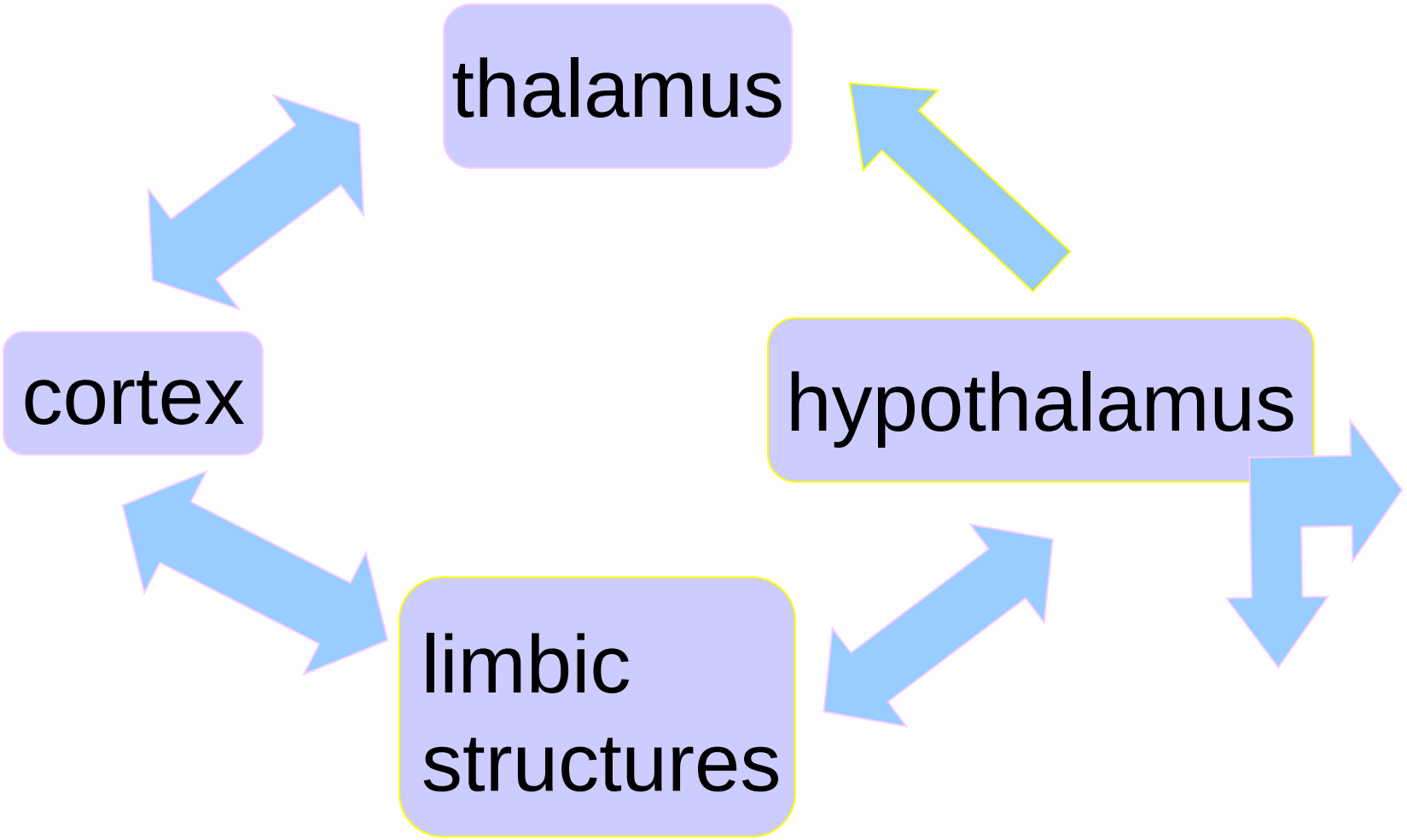
- Amygdala:

  learning and memory of emotional significance of stimuli

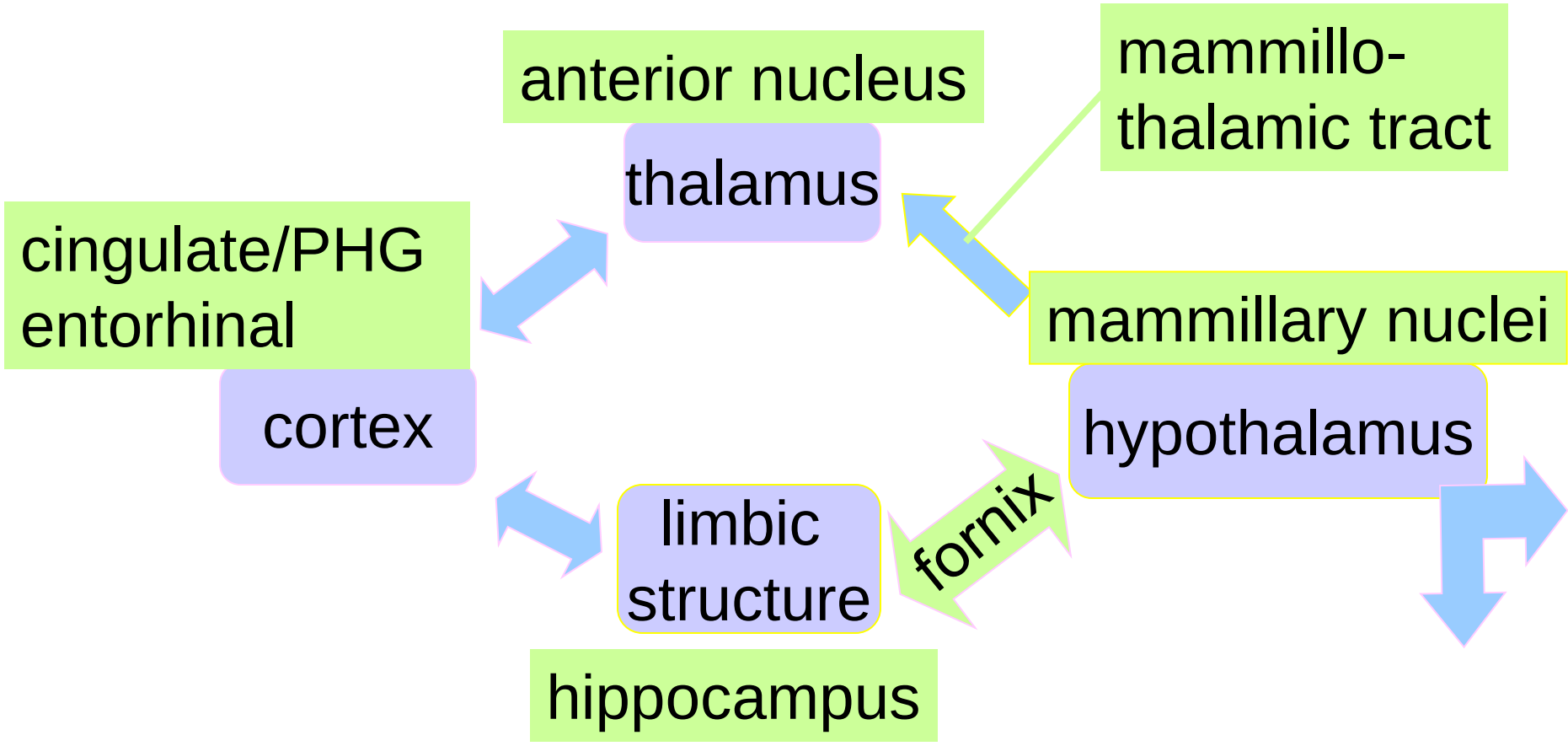
Limbic Cortex

It functions as a cerebral *association area for control of behavior …*

Basic limbic circuit: loop!

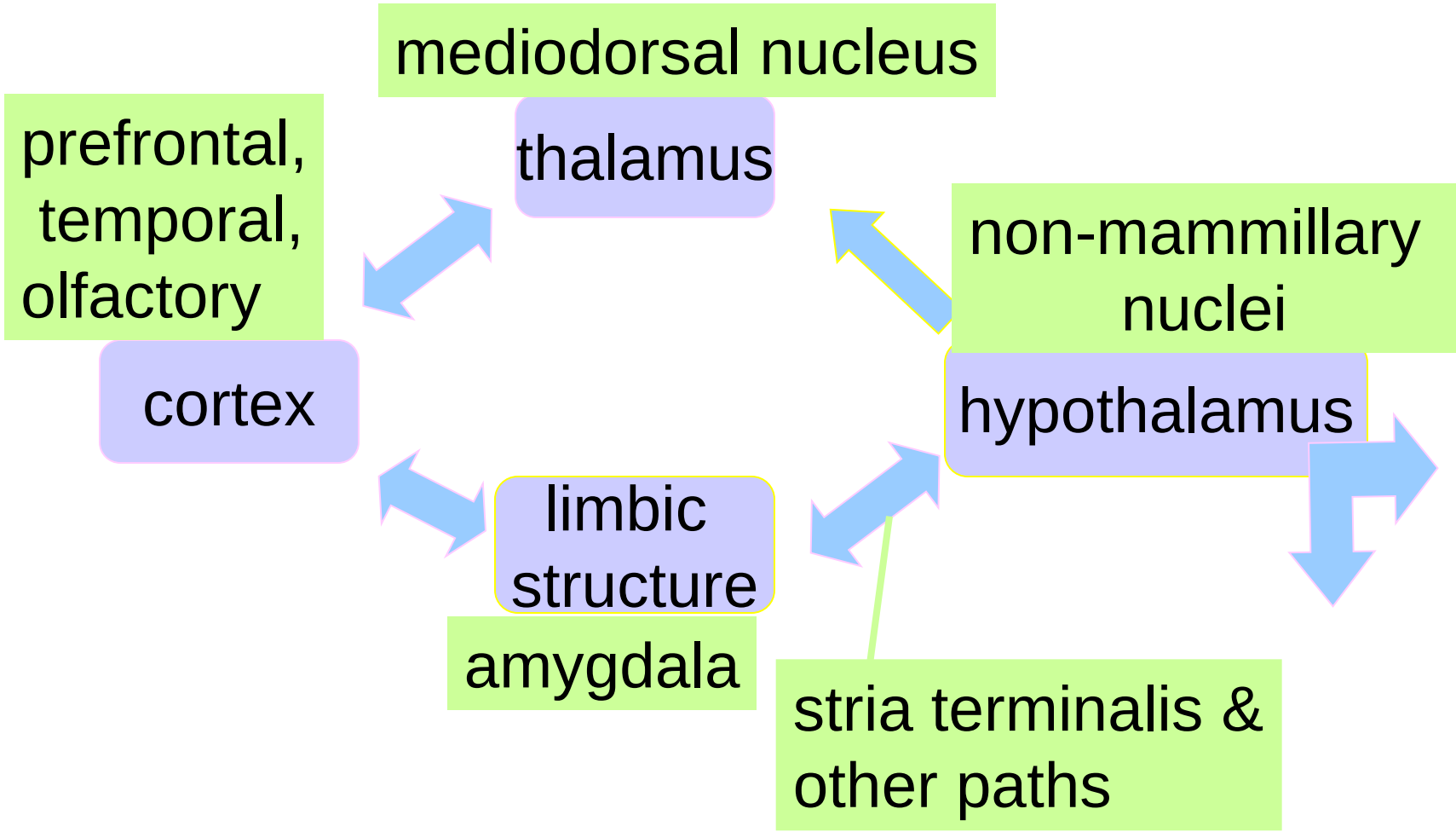


Hippocampal circuit



Papez circuit!!

Amygdala circuit



Summary

- Limbic structures and hypothalamus are highly interconnected with each other and with cortex and brainstem
- Amygdala orchestrates emotional and drive-related behavior through connections with brainstem, hypothalamus and cord
- Hippocampus is important for laying down new declarative memories