Introduction to Systems Neuroscience

Nov. 28, 2017

The limbic system

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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

cingulate gyrus
Sub-callosal gyrus
septal nuclei
uncus
parahippocampal gyrus
A major part of the limbic system is the hypothalamus with its related structures.

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

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).

POSTERIOR
- Dorsomedial nucleus (GI stimulation)
- Posterior hypothalamus (Increased blood pressure) (Pupillary dilation) (Shivering)
- Perifornical nucleus (Hunger) (Increased blood pressure) (Rage)
- Ventromedial nucleus (Satiety) (Neuroendocrine control)
- Mamillary body (Feeding reflexes)
- Arcuate nucleus and periventricular zone (Neuroendocrine control)
- Lateral hypothalamic area (not shown) (Thirst and hunger)

ANTERIOR
- Paraventricular nucleus (Oxytocin release) (Water conservation)
- Medial preoptic area (Bladder contraction) (Decreased heart rate) (Decreased blood pressure)
- Posterior preoptic and anterior hypothalamic areas (Body temperature regulation) (Panting) (Sweating) (Thyrotropin inhibition)
- Optic chiasm (Optic nerve)
- Supraoptic nucleus (Vasopressin release)
- Infundibulum
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

Hypothalamic 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 affective 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

**Figure 56–8**

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.

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
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
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
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
- Fearless
- Inappropriate social and sexual behavior
- 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.
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!

- Cortex
- Thalamus
- Limbic structures
- Hypothalamus
Hippocampal circuit

Papez circuit!!
Amygdala circuit

prefrontal, temporal, olfactory cortex

mediodorsal nucleus

thalamus

limbic structure

amygdala

non-mammillary nuclei hypothalamus

striata terminalis & other paths
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.