6. LIMBIC SYSTEM AND THE HYPOTHALAMUS

The limbic system is made up of many interrelated structures which coordinate memory processing, emotional behaviour, motivation and depression (Fig. 6.1). A key structure within this complex is the hypothalamus which receives sensory input with internal and environmental information. The hypothalamus processes this information and generates different outputs all tending to maintain homeostatic conditions.

In the upper lateral part of the limbic system we encounter the **cingulate gyrus** (Fig. 6-2). This area receives inputs and translates them into emotions which are then learned and committed to memory. Between the cingulated gyrus we find the **corpus callosum** which is a physical connection between the left and right hemispheres to permit neuronal communication between these areas. Ventral to the corpus callosum and the cingulate gyrus is located the **fornix** which interconnects the hypothalamus with the mamillary bodies, the thalamus and the cingulated cortex. The **mamillary bodies** connect through the fornix with other regions but are areas dedicated to memory recognition and to link specific memories.
memories with particular smells. Frontal to the mamillary bodies are the **olfactory bulbs** which are responsible to recognize smells, and associate them with specific memories. They also play a role discriminating odors and disregarding background non-threatening odors. Ventral and lateral to the fornix is the **thalamus** which communicates upwardly with the cerebral cortex and downwardly with the brainstem. Given its location it becomes a central relay for sensory and efferent information. It is believed that the thalamus encode sensory information before sending it to the cerebral cortex. The thalamus process information from the gustatory, auditory and visual systems, as well as visceral and somatic information from the body. It does not process olfactory information as this is dealt with by the olfactory bulbs. Same areas of the thalamus are responsible for regulation of sleep and wakefulness while others are involved in connections associated with state of consciousness.

Laterally to the brainstem and dorsal to the thalamus in what is called the medial temporal lobe of the brain is located the **hippocampus**. This structure is responsible for development of long term memory and spatial location memory. Although part of the hippocampus the **dentate gyrus** which is located in its caudal part plays a specific role in the formation of memories and in the sense of depression. The hippocampus is one of the first structures affected by Alzheimer’s disease. Immediately frontal to the hippocampus is located the **amygdala**, area dedicate to process and memorize emotions. The hippocampus is surrounded by the **parahippocampal gyrus**, an area dedicated to encoding and retrieval of memories. Although not part of the limbic system the **basal ganglia** is located laterally and frontally to the thalamus and it is one of the many areas related to control and learning of motor function. This area is directly affected by Parkinson's disease.

**Hypothalamic connections**

- Autonomic nervous system
- Diencephalom and cerebrum
- Hypophysis

**Hypothalamic nuclei**

- Dorsal H nucleus
- Paraventricular nucleus
- Anterior H nucleus
- Lateral H nucleus
- Medial Preoptic nucleus
- Supraoptic nucleus
- Supra-chiasmatic nucleus
- Arcuate nucleus
- Periventricular nucleus
- Lateral Preoptic nucleus
- Ventromedial nucleus

**Figure 6-3. Main areas of connection of the hypothalamus**

**Figure 6-4. Location of the different hypothalamic nuclei. (The first or last letter of the name is in contact with the corresponding structure)**
The smaller structure appears to be the mayor control center for all limbic functions. This is the hypothalamus which is centrally located under the thalamus. The hypothalamus contains a large number of specific nuclei or groups of neurons which carry out similar functions. Although the limits of each nuclei are not sharply delineated each hypothalamic nuclei is recognized to have one or more a specific functions. All the functions of the hypothalamus are geared to maintain the body within a range of homeostatic conditions.

The hypothalamus connects with most structures of the limbic system, thus, it receives and process sensory information and generates information that can be distributed into three main categories (Fig. 6-3).

To the autonomic nervous system. This information reaches via the brain stem and the reticular formation of the mesencephalon as well as to through the pons and medulla oblongata.
To the diencephalon and cerebrum. This information reaches principally via the frontal area of the thalamus.
To the hypophysis. The information send to the hypophysis regulates the secretion of several hormones which control many vital functions of the body. (An entire section of the next physiology course is dedicated to this subject).

The better identified nuclei of the hypothalamus are listed in figure 6-5 and depicted schematically in figure 6-4.

As indicated above the functions of the hypothalamus are aimed at processing all sensory information and generate outputs that will lead to maintenance of homeostatic condition. As such the hypothalamus affects all functions of the organism. Instead of listing the identified role of each nucleus we will discuss areas of activities which can be influenced by more than one nucleus.

Thermoregulation
In response to thermal sensory information generated by surface receptors or by internal febrile or pyretic receptors, neurons in the preoptic area increase their activity. If the temperature of the circulating blood is elevated these neurons send efferent instructions for sweating and panting. Concurrently these neurons send instruction through the autonomic nervous system to trigger vasodilation of peripheral capillary vessels in order to dissipate heat more effectively. A longer term effect of a hot environment is a reduction in production of TRH to reduce metabolic activity and avoid excessive internal heat generation. If the peripheral sensory information
indicates that it is cold, or the temperature of the blood circulating through the hypothalamus is below the set point, then the activity of neurons in the preoptic area is reduced thus avoiding sweating or panting. At the same time all the thermal information (from the preoptic area, and sensory from skin and internal receptors) is integrated in the posterior hypothalamus close to the mamillary bodies to determine if the strategy to follow is to conserve or generate heat (Fig. 6-6).

**Cardiovascular control**

The hypothalamus control cardiovascular activity by modifying arterial pressure and heart rate. The efferent information is generated in several hypothalamic regions and it is sent via cardiovascular centers located in the reticular formation at the level of the pons and medulla oblongata to the target tissues throughout the body. Specifically elevation in arterial pressure and increase in heart rate is mediated by activity of neurons of the posterior and lateral hypothalamic nuclei, while neurons in the preoptic area decrease arterial pressure and reduce heart rate (Fig. 6-7).

**Regulation of feeding activity**

Two antagonistic centers regulate the actual feeding activity. The “hunger center” is made up of neurons of the lateral hypothalamic nuclei. Stimulations of these neurons trigger appetite and the associated food seeking behaviour. The antagonist center is the satiety center located in the ventromedial nuclei. Both of these centers have the ability to detect circulating concentration of key nutrients such as glucose to trigger initiation of feeding.
or cessation of feeding. Bilateral damage to the lateral or ventromedial nucleus triggers an absolute lack of desire to eat or an insatiable appetite, respectively. The result could be inanition leading to death or uncontrolled intake leading to obesity (Fig. 6-8).

**Water regulation**

There are two different but usually simultaneous mechanisms to control water content in the body. One relates to the ingestion of water and the other to the elimination of water from the organism. If the electrolytes in the circulating fluids are detected to be too concentrated, sensors located in the lateral hypothalamus, in what is called the “thirst center” as well as many other distributed throughout the organism trigger the desire to drink. If given the opportunity, the animal will drink an approximate amount of water to dilute the circulating fluids. The initial cessation of thirst is triggered by the presence of water in the mouth and humidity of the lips. This is a temporary effect that allows time for water absorption through the GIT to ultimately attain the dilution of body fluids (Fig. 6-9).

The second mechanism to regulate water content is conservation of water by reducing urine volume. This is regulated through neurons in the supraoptical nuclei which produce a neurohormone called antidiuretic hormone or vasopressin. This hormone reaches the collecting ducts of the kidneys and triggers reabsorption of water while...
letting electrolytes to be eliminated in the urine. This reduces the circulating concentrations of electrolytes bringing their levels to normality.

**Regulation of smooth muscle contractility**

A very discrete activity, mainly related to several reproductive events is controlled through neurons in the **paraventricular nuclei** of the hypothalamus. These neurons produce the hormone oxytocin which stimulates contraction of myoepithelial cells typical of smooth muscle. These muscle fibres are found in the uterus in the mammary gland. At birth the pressure of the fetus sends sensory afferent information to the hypothalamus which responds by secreting oxytocin. This hormone triggers contractile activity in the uterus to expel the fetus. During lactation stimulation of the mammary gland also triggers secretion of oxytocin which in turn stimulates contractile activity in the mammary gland to push the milk out of the alveoli. The stimulus can be done manually, (cleaning the mammary gland before milking) by the young while suckling and also can be triggered by classical conditioning (the cow hears the sound of the milking cans and start producing oxytocin) (Fig. 6-10).

**Hypothalamic neuroendocrine function.**

Several of the hypothalamic nuclei have the ability to produce neurohormones that will stimulate or inhibit the secretion of other hormones by the pars distalis of the hypophysis. The trigger for the production of these hormones is the concentration of several compounds in circulation which are detected as blood passes through the hypothalamus. (We will deal with this subject in the winter semester).