

# The Diencephalon

(Slides 31-35)

We have completed our discussion of the telencephalon, the large cerebral hemispheres at the top of the brain. We are now moving into the brainstem. The diencephalon is at the top of the brainstem and is sometimes referred to as the upper brainstem, although some references reserve the name "brainstem" for the structures below the diencephalon (the "three Ms") and consider the diencephalon to be part of the forebrain. In this class, we will adopt the more common convention that the diencephalon is the upper brainstem.

"Di" mean two. The diencephalon consists of two major structures, the thalamus and the hypothalamus. To be completely correct, you should be aware that two other regions are also usually included as part of the diencephalon, the epithalamus and the subthalamus. These structures are functionally more closely related to the limbic system and basal ganglia, and we will not deal with them in any detail.

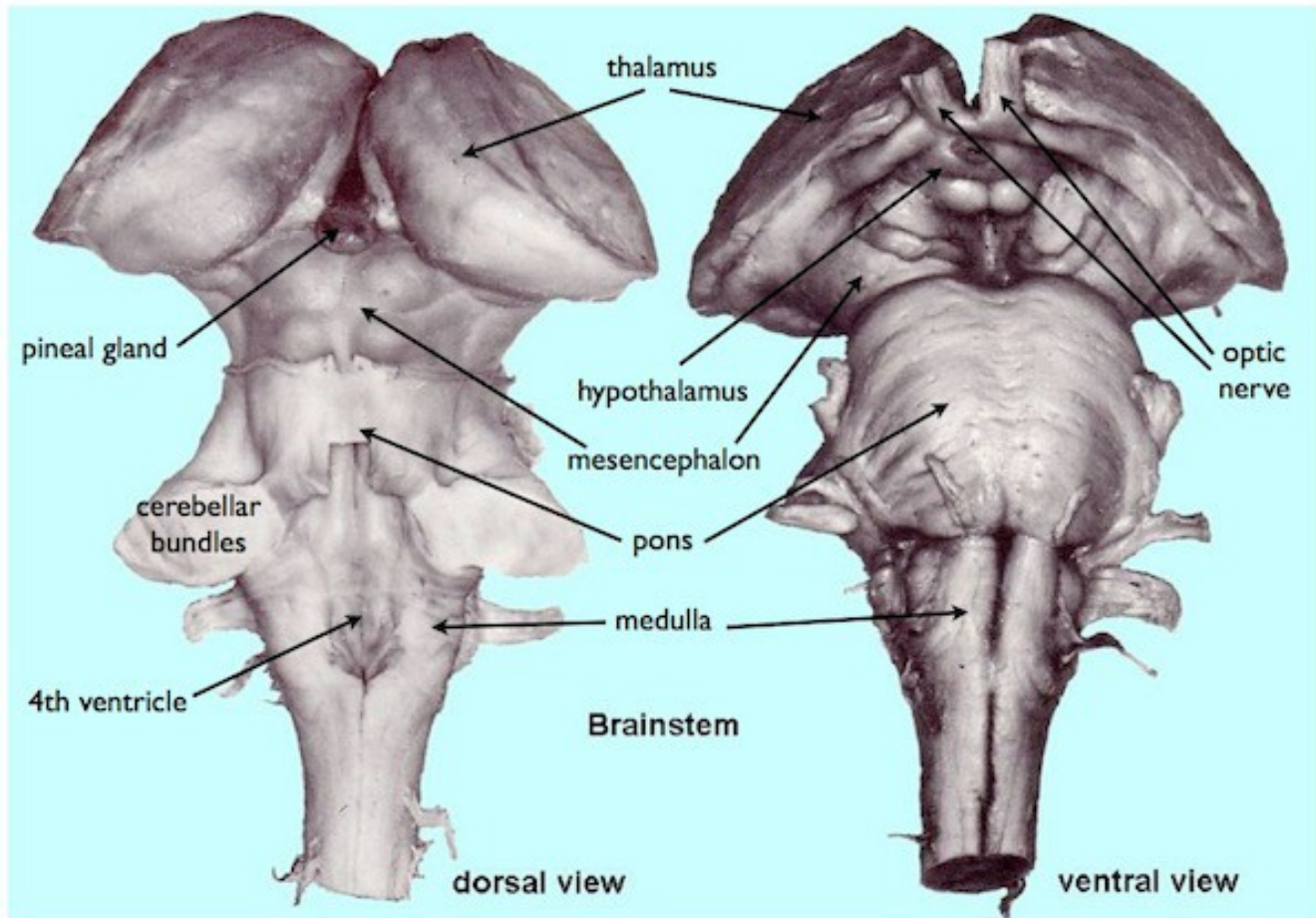
(See slide 32.) Slide 32 shows the brainstem in isolation from the rest of the brain, the cerebral hemispheres and cerebellum having been dissected away. On the right is a dorsal view. At the top, the two large egg-like structures are the thalamus (one on each side of the brain). Between the two thalami is a darker bulb-like structure, the only unpaired structure in the brain. This is the pineal gland (part of the epithalamus). Descartes believed that the pineal gland, due to its unpaired nature and its location near the center of the brain (it is not in the exact center as some sensationalistic websites would have you believe), was the place where the brain and the soul interacted. Today we know that the pineal gland is just that, a gland, secreting as its primary hormone a substance called melatonin.

Below the thalamus and pineal gland in this dorsal view, we see four (two pairs of) mounds. This is the dorsal roof of the mesencephalon. Below the mesencephalon is the pons, and you can see two large fiber bundles connected laterally to the pons that have been cut. These would usually connect to the cerebellum, which has been dissected away. Between these two cut bundles is a small cavity, which is the fourth ventricle. Surrounding the 4th ventricle below the cerebellar bundles is the medulla or myelencephalon. We'll come back to all of this later. A midsagittal view of many of these structures can be seen on slide 25.

The image on the right of slide 32 shows a ventral view of the brainstem, once again with the cerebral hemispheres and cerebellum dissected away. At the very top is the thalamus. In front of the thalamus you can see two stumps of a cut nerve, which appears to form a sort of X and then continue back into the brain along the bottom of the thalamus. This is the optic nerve, carrying visual information from the retinas. It will terminate in the thalamus, as we will see shortly.

Below the X formed by the optic nerve is a suspicious looking area that terminates in two large swellings. This region is the hypothalamus. A little puckered spot on the ventral surface of the hypothalamus, just behind the X of the optic nerve, is where the pituitary gland would ordinarily be attached.

Below and lateral to the hypothalamus is the mesencephalon, with a large cranial nerve lying across its ventral surface. You will know what this cranial nerve is and what it does in good time. Below the mesencephalon is a large area with lateral striations, the pons. Below the pons is the medulla, which in this view looks like two large columns. The following diagram may help you identify some of these structures.

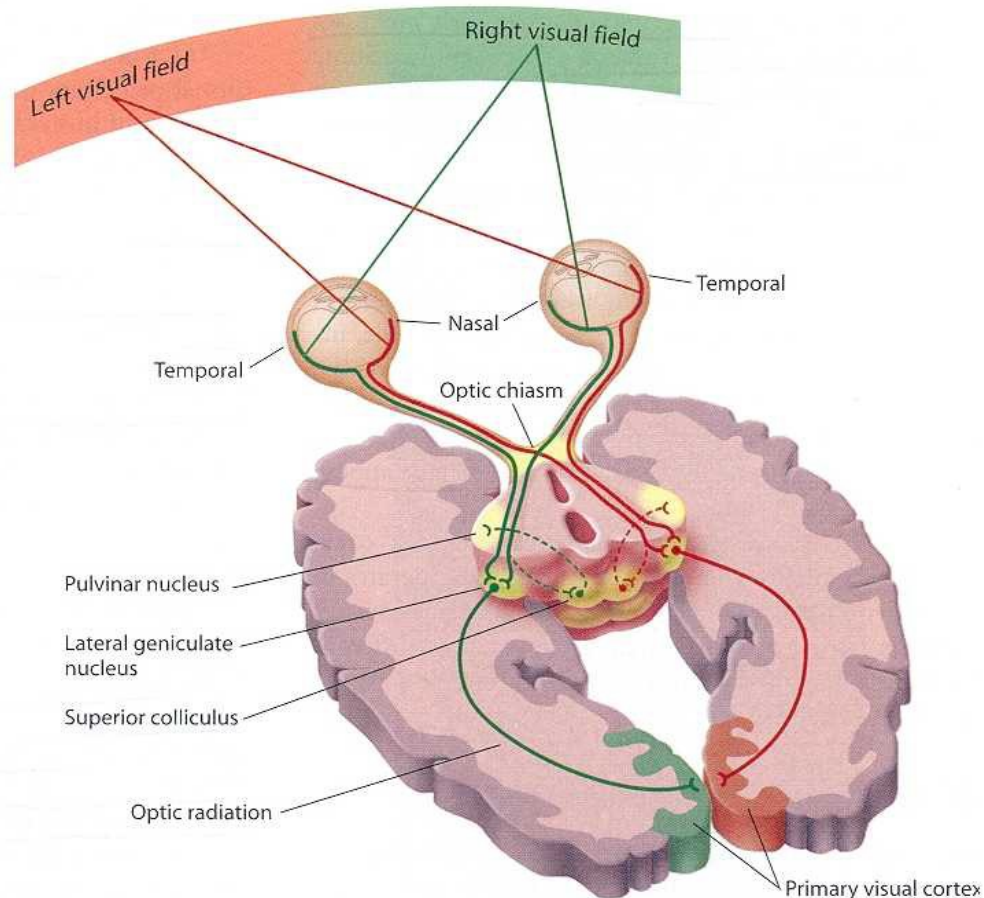


### The Thalamus

(See slide 33.) Be careful with slide 33. On the left is a fellow whose head and cerebral hemispheres are transparent (not the usual circumstance) so that you can see the top of his brainstem. As you can see, the front of the thalamus is towards the left in this diagram. On the right side of slide 33 is a diagram of the thalamus that has been removed from the head and bisected. In this diagram the front of the thalamus is towards the right.

Notice that the thalamus is not a unitary structure, but rather is made up of about 25 individual nuclei. (For a complete list, if you're curious, see [https://en.wikipedia.org/wiki/List\\_of\\_thalamic\\_nuclei](https://en.wikipedia.org/wiki/List_of_thalamic_nuclei).) These nuclei can roughly be classified into three types: relay nuclei, association nuclei, and nonspecific nuclei. Relay nuclei are mostly those labeled on slide 33. They receive specific inputs, usually sensory, and relay these to specific functional areas of the cerebral cortex, such as the primary visual cortex. There are four of these that I would like you to know, highlighted in yellow on slide 33: the lateral geniculate nucleus (or body), the medial geniculate nucleus (or body), the ventral posterior nuclei, and

the ventral lateral and ventral anterior nuclei. Notice that both of the geniculates sort of hang off the back of the thalamus. They apparently reminded the early anatomists of knees, hence geniculate, or knee-like. As you can see, the lateral geniculate relays to the primary visual cortex of the occipital lobe and, thus, is part of the visual pathway. That is to say, the optic nerves terminate or make synapses in the lateral geniculate. Cell bodies in the lateral geniculate then project their axons back to the primary visual cortex of the occipital lobe. The medial geniculate relays to the primary auditory cortex of the temporal lobe and, thus, is part of the auditory system. We will deal with these systems in more detail when we discuss cranial nerves, but since I've already pointed out the optic nerve to you, here is a simple diagram of how that system is wired up.



Notice that the optic pathways are partially crossed in such a way that objects in the left visual field are seen in the right visual cortex, and vice versa. The partial crossing occurs at the X that was pointed out above (ventral view of the brainstem--slide 32). This X is called the optic chiasm. Notice also that, although the eyes are conveniently located on the front of your head, the area of the cortex that receives input from them is all that way at the back of your brain. If you reach around to the back of your head and feel for a little bump (oh, go ahead--nobody's watching!), the occipital lobe and visual cortex are located just above that bump.

The ventral posterior and related nuclei are similar relays for the somatosensory system. Input comes from touch and related senses and is relayed to the primary somatosensory cortex in the postcentral gyrus of the parietal lobe.

The ventral lateral and ventral anterior nuclei are motor relay nuclei. They relay impulses coming from the basal ganglia and the cerebellum into the motor cortex of the frontal lobe.

Other nuclei in the thalamus are association nuclei. These nuclei receive input from one area of the cerebral cortex and project back to another, usually an area of association cortex. Examples are the pulvinar and the mediodorsal nucleus, which are clearly labeled on slide 33.

The intralaminar and midline thalamic nuclei are the nonspecific nuclei. They receive input from the reticular formation of the lower brainstem (to be discussed) and may be important in regulating the sleep-waking cycle and in modulating other functions of the thalamus.

Thus, you can kind of think (roughly) of the thalamus as a switchboard into the cerebral cortex. If specific information, e.g., sensory information, is getting into the neocortex, it's being relayed through the thalamus first. You may have heard in another of your psych classes that this doesn't apply to olfactory (smell) information, but that's not correct. A lot of olfactory information by-passes the thalamus, but that info is headed into the limbic system and limbic cortex. If it's headed to the neocortex, it's going through the thalamic relay system first.

## The Hypothalamus

(See slide 34.) The hypothalamus is smaller than the tip of your little finger yet is even more anatomically complex than the thalamus. I'll try to keep it as simple as possible for you, but no simpler. Consider the hypothalamus to have four basic functions (slide 35).

One, the hypothalamus is so intimately interconnected with the limbic system that some sources consider it part of the limbic system. We won't, but I once got in trouble with one of my graduate professors by implying that it is not, so know what your professor wants! In a way, the hypothalamus is kind of the thalamus of the limbic system. Thus, damage in the hypothalamus can have many of the same consequences as damage in the limbic system, notably emotional changes and amnesia.

Two, the hypothalamus connects to and controls the pituitary gland. This is done in two ways. The anterior part of the pituitary is controlled by substances (releasing factors) that are released into the blood by the hypothalamus. The posterior pituitary gland receives direct neural input from the hypothalamus. Since the pituitary gland is the "master gland" of the endocrine system, the hypothalamus can be thought of as controlling the body's endocrine system, which includes sex hormones, stress hormones, and all the rest.

Three, there is a branch of the peripheral nervous system that does not connect directly to skeletal muscles or sensory organs but to internal organs, blood vessels, etc. This is called the autonomic nervous system, which we will discuss in more detail when we talk about the peripheral nervous system. The autonomic nervous system is sometimes said to be in control of "vegetative functions." In turn, the hypothalamus sits at the top of and regulates the autonomic nervous system.

Four, the hypothalamus regulates what are sometimes called homeostatic drives. These are drives that can turn themselves on and off, such as hunger and thirst. When the brain is signaled that there is an insufficient supply of nutrients in the blood, the brain turns on eating to restore that supply. When the

body detects that the supply has been sufficiently restored, it signals the brain, which then turns off eating. (That's considerably oversimplified, but that's basically the way it works. It's rather like a heater operated by a thermostat. If the air temperature falls too low, the thermostat turns the heater on. The heater warms the air. The thermostat detects the warmer air and turns the heater off.) Body temperature, sex drive, sleep-waking, and other circadian rhythms are also at least partly under the control of the hypothalamus.

To take hunger as an example, there are two areas of the hypothalamus that seem to play a key role in food intake, the lateral hypothalamus (LH) and the ventromedial hypothalamus (VMH). Two functions have to be regulated, hunger (eating on) and satiety (eating off).

In the early 1940s, Hetherington and Ranson discovered that making lesions in the hypothalamus of a rat that destroy the VMH on both sides of the brain can result in the rat overeating and becoming obese, sometimes even doubling or tripling its body weight. The theory was developed that the VMH is a satiety center, i.e., it turns off eating when the rat is no longer hungry. This theory has been controversial, but recent research seems to confirm that the VMH plays a crucial role in satiety. One possible mechanism is that the VMH contains receptors for a hormone called leptin. Leptin is released by healthy, well nourished fat cells (adipose tissue). Thus, if leptin is being detected by the VMH, it means the rat can cool it on the food intake front. Lesions of the VMH destroy this leptin detecting ability and, thus, lead the rat to eat itself into obesity. Whether or not the VMH plays a role in human obesity is unknown.

## Hetherington and Ranson (1942) The VMH Rat



Satiety - the feeling or state of being fully satisfied. Satiety centres function is to stop feeding

Made lesions on an area of the VMH (part of the hypothalamus) in rats.

Caused the rats to overeat and be dramatically obese.

This lesion destroyed a centre that is vital for the control of feeding behaviour. Its destruction led to an **increase** in feeding and body weight.

It was assumed that this was a satiety centre - which is normally activated when the animal is full at the end of the meal.

source: [www.slideshare.net](http://www.slideshare.net)

On the other hand, it was discovered that lesions which destroy the lateral hypothalamus bilaterally have the opposite effect. The rat stops eating and sometimes will even starve itself to death if special care isn't taken of it. (There is not much you can get an LH rat to eat, but in my experience, you can keep them alive by feeding them mashed up chocolate chip cookies soaked in milk. They seem to like that, and who can blame them!) More recent experiments have shown that injections of NPY (neuropeptide Y) into the lateral hypothalamus will make rats eat ravenously. NPY (and other hormones) seems to be the signal that turns on eating. If the LH is damaged and cannot detect NPY, eating will not occur, and the rat will starve. The final decision as to whether you are going to eat or not seems to be made in another nucleus of the hypothalamus that receives input from the LH.

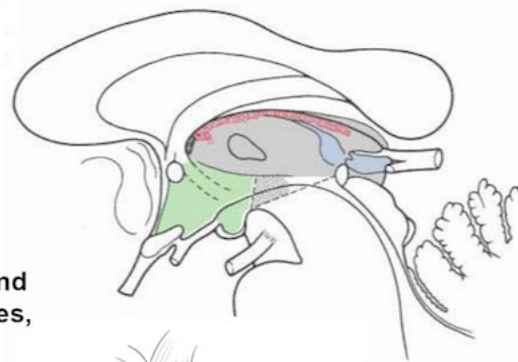
The LH syndrome in rats very much resembles anorexia nervosa in human beings. Whether the two syndromes are somehow related is not known.

Control of hunger (and thirst) by the hypothalamus is quite complex and is covered in more detail in Psyc 460, for those who are interested. We have only scratched the surface in this discussion.

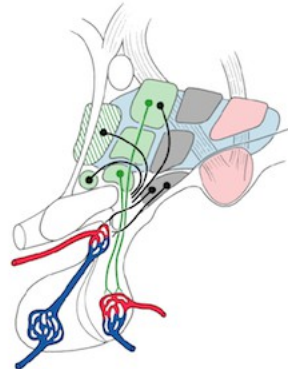
## Overview of the Hypothalamus

### Functions

- Homeostasis
  - food intake / metabolism
  - water & electrolyte balance
  - temperature regulation
  - circadian rhythms
- Endocrine control via the pituitary gland
  - growth hormones, stress hormones, reproductive hormones, etc.
- Autonomic control
  - integrates sensory information, memory, and emotion to organize sympathetic and parasympathetic responses
- Limbic functions
  - memory & emotion



HT 15-4



HT 30-5