

# Diversity and Adaptations of the Brain: Introduction to Brain Structure

Melissa K. Demetrikopoulos, Ph.D.  
Center for Behavioral Neuroscience

The brain is a truly fascinating structure! It allows one to control the rest of the body and so is involved in all the bodily functions such as digestion (getting nutrients from food), respiration (bringing in oxygen to the lungs), and circulation (having the heart beat and bringing nutrients and oxygen to all the cells of the body through the blood). Additionally, the brain allows one to do many fun things such as running and playing soccer by its control of one's muscles. It is the organ that is responsible for such things as one's ability to think, remember, and have emotions. Thus, the brain is the center of all of one's activities.

## I. Building Blocks of the Brain

The main cells that make up the brain are neurons. These cells communicate with one another by means of electrical and chemical signals. Unlike most of the other cells in your body, neurons do not divide and thus if they die, they are not replaced. This is why it is so important to take care of your brain. Luckily, we seem to be able to function with the loss of nerve cells that normally occurs with aging. However, one can damage their brain by poisoning it with chemicals, getting dehydrated, or blocking the supply of oxygen and nutrients to the brain.

## II. Parts of the Brain

Although the brain is a single organ, it is very complex and has several main parts to it. Each of these parts have a main function, or job, but they all must work together and in coordination with the rest of the body to work.

### A. Hindbrain

Although the hindbrain is primitive it is quite important since it is the part of the brain that keeps one's body alive. The hindbrain is made up of the medulla oblongata, pons, and cerebellum. It is where subconscious processes like heart rate, respiration (breathing) and digestion (break down of food) take place. The first area above the spinal cord is called the medulla oblongata. The medulla is particularly important since it is the main area that controls the heart and lungs. The medulla also contains a site that makes one vomit (throw up) called the emesis center. The next area is called the pons. The pons is a part of the brain that allows other parts of one's brain to communicate (talk). It is the region that allows the cerebral cortex to communicate with the cerebellum. The cerebellum is the part of the brain that is located on the back of the brain near the base (bottom). It is the part of the brain involved in coordination and balance. The cerebellum allows one to learn complicated things like typing, writing, playing the piano, riding a bike, walking a tight rope, hitting a home run, and so on. Information from the eyes and muscles is sent to the cerebellum so that one knows how the body is positioned (this sense is called proprioception).

### B. Midbrain

The midbrain is the region that allows one to move the head and eyes in a way that one can turn to look at something. It is also an important area for acts of aggression (fighting). The medulla, pons, and midbrain are sometimes termed the brain stem. This is the most primitive area of the brain and has been called the reptile brain. The reticular formation is a group of neurons in the brain stem that is important in keeping one alert (wide awake) and concentrated. It is the part of the brain that allows one to listen to a friend in a busy restaurant even though there are many other people talking and dishes clanking all around.

### C. Forebrain

The hypothalamus is part of the brain that controls the autonomic nervous system in addition to the regulation at the level of the brain stem. Thus, the hypothalamus is important in controlling all of the bodily organs including the heart, lungs and intestines, as well as controlling body temperature and effecting immune function. In addition to its control of the autonomic nervous system, the hypothalamus controls the pituitary gland that secretes a number of different hormones that effect the body. There are many subregions within the hypothalamus that have special functions such as an area which tells one to stop eating when one is full (ventral medial hypothalamus) and another region that tells one to start eating when one is hungry (lateral hypothalamus). There is also a specialized region that serves as our internal clock and provides the cycle of one's day called the circadian rhythm.

The thalamus is located just above the hypothalamus and is the portion of the brain that relays the sensory information to the cortex. It too has many sub-regions that each deal with a particular sense such as gustation (taste), tactile (touch), olfaction (smell), auditory (hearing) and vision (sight).

The cerebral cortex is the most advanced area of one's brain. This is where thinking, talking, and understanding take place. It is also the main coordinator of all of the other areas of the brain. The cerebral cortex has many convolutions (folds) that increase its area. It is generally thought that the two cerebral hemispheres (halves) have different functions with the left hemisphere controlling math and speech and the right hemisphere controlling more creative endeavors. Interestingly, the right hemisphere controls the muscles on the left side of one's body. The two sides of the cerebral cortex are connected by the corpus callosum allowing coordination of movement and integration of information. In addition to the lateral (right/left) distinctions in the cerebral cortex, there are several distinct lobes. The frontal lobe is at the front of the brain and communicates greatly with the limbic system in processing emotional and painful information and the frontal lobe has the primary motor region that deals with voluntary body movement. The parietal lobe is behind that (caudal) and contains the primary sensory region and deals with the integration of sensory and motor information. The temporal lobe is located behind one's temples and is very important in the auditory (hearing) sense and with memory. The last lobe is the occipital lobe and is at the back of the brain just above the cerebellum. This is where visual information is processed---(Perhaps your grandmother can see out the back of her head!?)

The limbic system is the center of emotions. It is the part of the brain that makes one happy or sad. The same event or object may produce either emotion depending on the memories one has linked to that event or object. For example, one might generally be happy looking at a picture of one's grandmother. However, shortly after one's grandmother dies, looking at the same picture may make one sad. The picture has not changed, but one's reaction to it has by way of memory and associations with the picture. One region of the limbic system is the hippocampus. The hippocampus is the part of the brain most involved in learning and memory. The amygdala is a very important part of the limbic system and serves as a mini-cortex in that it is able to process emotional inputs. It is very important for the effects of olfactory (smell) information on emotions and also critical for the production of fear and aggression. The amygdala also communicates with the hypothalamus and thus can effect things like heart rate so that your heart starts pounding fast when you are excited.

### III. Brain Adaptations

So far the discussion has been centered around the human brain. Just as different animals have different external characteristics, they also have different adaptations of the brain. In fact, invertebrate animals do not have a brain at all but instead have one or more ganglia. These ganglia are groups of neurons that work together but lack the more complex structure of the brain. Vertebrate animals also have ganglia in various regions of the body in addition to the brain.

#### A. General Adaptations

One of the more obvious brain adaptations is brain size. Since larger animals need larger brains in order to control more muscles and bigger systems, it is not surprising that a mouse has a smaller brain than a cat. However, overall brain size is less important than the relative brain size--the brain size adjusted for body weight. In fact, in general, men have slightly larger brains than women (just as they generally have larger hands) but they do not differ in

intelligence. Furthermore, if two species of animals had the same brain weight, it would be likely that the species with the lower body weight would be more intelligent. One way to increase brain weight while maintaining the same brain size is to pack the neurons in more densely. One of the ways this is accomplished is by the convolutions (folding) of the cerebral cortex. Thus more advanced animals tend to have a more complicated cerebral cortex. Animals with a relatively smooth cerebral cortex are called lissencephalic while animals with a very convoluted cerebral cortex are called gyrencephalic. One clear example of this is a comparison of the bottle-nose dolphin to the manatee. Additionally, more complex animals have a greater relative size of the cerebral cortex (as it relates to the total brain size) so that the cerebral cortex comprises a greater proportion of the overall brain.

Another obvious feature of the brain is the relative size of the cerebellum. As you remember, the cerebellum is important for balance. So if one compares the flying lemur to the ring-tailed lemur one can clearly see a proportionately larger cerebellum in the flying lemur that allows them to have greater aerial daring stunts. Similarly, a cat has a proportionately larger cerebellum than a dog and thus is much more coordinated than the dog and can perform stunts like landing on their feet. (For dog lovers out there, be sure to compare their cortical convolutions and one could argue the dog is more intelligent).

Another feature that is easily seen on the brain is the size of the olfactory bulb. The olfactory bulb is important for the sense of smell. In humans, the olfactory bulb is quite small and can be seen on the underside of the brain. However, in the mouse the olfactory bulb is relatively large and accounts for a significant portion of the overall brain. The olfactory bulb on the mouse can be seen sticking out in front of the frontal cortex. The Tasmanian devil also relies heavily on the sense of smell and has enormous olfactory bulbs. Another group of animals with large olfactory areas are sharks and rays.

#### B. Adaptations by Classes of Vertebrates

Vertebrates are divided into 5 classes pisces (fish), amphibians, reptiles, aviary (bird), and mammals. Although all vertebrates have three main brain regions, the forebrain, midbrain, and hindbrain, there are many adaptations by these classes in their neuronal structures. For example, the components of the cerebellum vary greatly across classes. Fish have the most primitive cerebellar organization since they do not need to support their weight on land. The amphibian and reptilian cerebellums are quite similar and are intermediate in complexity. The most complicated cerebellums are present in birds and mammals. Both the mammalian and avian cerebellums are convoluted (folded) and the mammalian cerebellum has a much more complicated pattern of development. The avian cerebellum has a central region that is highly developed for flying while the mammalian cerebellum has a lateral (sideways) expansion. Bat brains have one of the most interesting cerebellums since they have both the lateral expansion that you see in mammals and the highly developed central region for flying. One can see that as the cerebellum increases in complexity across classes of vertebrates, the ability to perform more complicated tasks and finer control of movements were developed.

Although not obvious from an external (outside) examination of the brain, the limbic system shows great differences across vertebrate classes. In fact, some scientists believe that the limbic system did not truly exist until mammals that would suggest that the lower classes of animals do not have emotions the same as mammals. However, even fish can learn to avoid areas where punishments were given so it is likely that the functions of the limbic system are present in these other classes in some modified form.

The largest distinction among the vertebrate classes is the expansion of the cerebral cortex. The forebrain is the area of the brain that one can see the most changes in across the vertebrate classes. Mammals have the relatively new structure of a neo-cortex that is not present in lower animals. The changes in the forebrain across the classes are some of the most prominent differences in the various classes. In fact, the frontal lobes of the cortex, and specifically the prefrontal cortex at the very rostral (front) part of the frontal lobes are more elaborate and larger in humans than other primates. The prefrontal cortex is important for planning, complex intellectual activities such as sorting a deck of cards and the emotional response to pain.

#### IV. Further Reading

##### Pre-college

The Big Head: A Book About Your Brain and Your Head by Pete Rowan, (1996) Random House Inc, NY.

##### College level

Comparative Vertebrate Neuroanatomy: Evolution and Adaptation by Ann B Butler and William Hodos, (1996) Jon Wiley and Sons, NY.

Brain Images can be obtained from the Comparative Mammalian Brain Collections of University of Wisconsin, Michigan State University, and the National Museum of Health and Medicine. Preparation of all these images and specimens has been funded by the National Science Foundation as well as by the National Institute of Health.

<http://brainmuseum.org/>

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[http://www.cbn-atl.org/edu\\_resources/web\\_review.html](http://www.cbn-atl.org/edu_resources/web_review.html)

Note: This introduction is helpful for playing the Marine Mammal Brain Game and for the Build a Brain Activity

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