CHAPTER 1

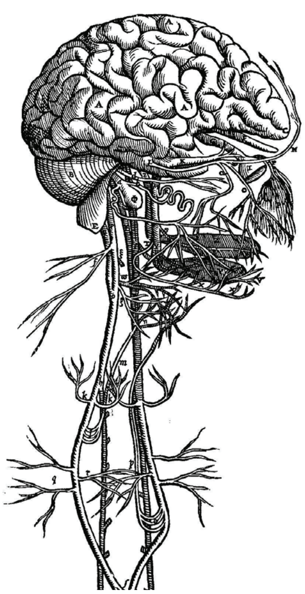
A VERY BRIEF HISTORY OF BRAIN RESEARCH

Even before reading this book, you already know more about the brain than the doctors and scientists of the ancient world up until about 300 B.C. If you've done any reading at all about the brain, you probably know more about the brain than anyone in the Medieval world did. Brain research did not really begin until the late 1800s, and progressed slowly until the invention of scanning devices in the late 1900s. Even today, in the 21st century, with all our advanced medical technology, there is a lot we don't know about the brain.

In about 300 B.C., the famous Greek thinker, Aristotle, proposed that the heart was the center of thought and emotion, and that the gray blob inside the head only served to cool the blood after it got all heated up by the heart. He was followed by a Greek doctor named Herophilus who actually cut bodies open to see how they worked. After studying the anatomy of the brain and making observations of what happened to people when they got hit on the head, he decided that the brain, not the heart, must be the control center of the body. Herophilus also noticed long, threadlike things running out from the brain to parts of the body. Today we call these things ***nerves***.

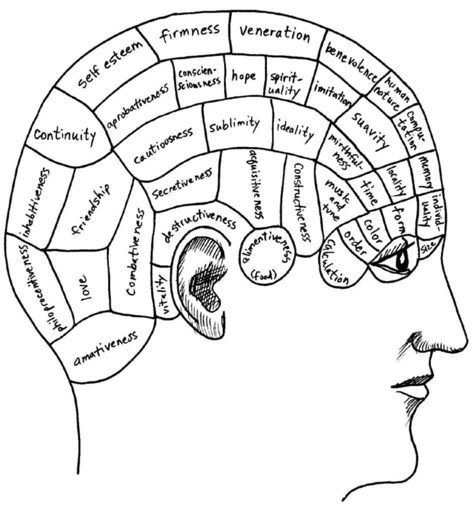
ARISTOTLE
384-322 BC

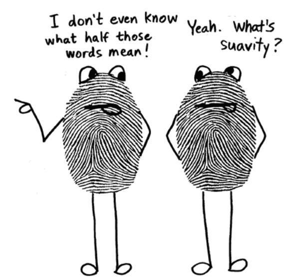
Another Greek doctor, Erasistratus, opened skulls to look at brains. He described all the wrinkles and folds that we now call ***convolutions***. He even noticed that human brains have more of these convolutions than the brains of animals do. He also saw that the brain has two main sections, and that it is covered by thin membranes. After Erasistratus, a doctor named Galen began poking around at the nerve stem that comes out of the bottom of the brain. He did experiments with animals where he cut this stem at various points and observed the results. Injuries up high on the stem caused death. Injuries lower down on the stem caused only paralysis of body parts. From this he learned that what we now call the ***brain stem*** is in charge of basic functions like making the heart and lungs work.



After Galen, not much happened in the world of brain science for about a thousand years. Then a doctor named Andreas Vesalius came on the scene in the 1500s. His work was the beginning of modern medical science, as he dissected bodies more scientifically than anyone had ever done before. He figured out that the brain, the spinal cord, and all the nerves in the body make up a complete nervous system. His anatomy books were used by medical schools for hundreds of years. The picture to the left is one of his drawings.

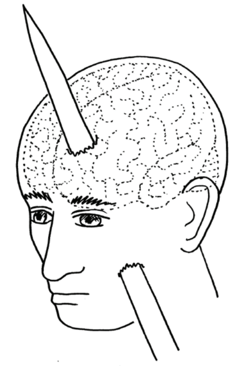
Even with all of Vesalius' wonderful drawings of the brain and spine, still no one knew exactly how the brain worked. Right into the mid 1800s, doctors were clueless as to how that gray blob actually worked. Did the whole brain function as a unit, or was it subdivided into specialized areas? How did it send messages to the muscles? No one knew. That didn't stop people from guessing, though. One theory was that the brain had many specialized areas for certain activities. Someone came up with a map of the brain and labeled each area. People believed that areas of your brain that were large (and therefore your strong points) would cause your skull to bulge just a little. Therefore, you could tell someone's personality by feeling the bumps on their head! This "science" was called ***phrenology***. Believe it or not, diagrams like this were taken seriously right up until the mid-1800s (the era of the American Civil War). Some scientists did not believe this theory, and they were always arguing back and forth as to whether the brain functioned as a whole or was divided up into areas. Modern science has proven that both sides were right AND wrong. The brain does indeed function as a whole, and the brain does indeed have specialized locations for certain activities.





In the late 1800s, brain researchers discovered that the best way to find out how the brain works is to study brains that have been injured. After an injured patient died, they would examine the brain to find out which area (or areas) had been damaged. They discovered that in patients who had lost the ability to speak, there were always damaged cells on the left side of the brain in the area behind the temple. In patients who had lost the ability to move their arms or legs, there was always damage on the top of the brain. The researchers kept track of their findings, and began a new map of the brain, one based on observation, not on wild guesses.

The most famous brain injury of all time happened to a man named Phineas Gage. He lived in the state of Vermont and worked on the railroad as the foreman of a blasting crew. His job was to use dynamite to blast away rock that was in the path of the new railway. He would use a long metal tool called a tamping iron to press gunpowder down into deep holes. One end of the rod was sharp so that it could be used to break apart stubborn clumps. On September 13, 1848, he accidentally dropped his rod into a gunpowder hole. The explosion sent the rod up through his head, entering under his jaw and coming right out the top! He survived the accident and seemed to make a complete recovery. Those who knew Phineas well, however, said that his personality changed after the accident. They said that "Gage was no longer Gage." He was restless, had trouble making decisions, and was often rude. The rod had damaged the front of the left side of the brain, the area containing our social skills and our ability to make rational decisions. Eventually, the injury did begin to affect his bodily health and he began having seizures (more on his symptoms in later chapters). He died of a seizure 11 years after his accident.



Modern brain researchers have the benefit of high-tech scanning devices that allow them to look at the brains of living patients (without harming the patients, of course). These scans are known by their initials, CT (or CAT), MRI, and PET. The CT scan uses X-rays, the MRI uses magnetism and radio waves, and the PET traces radioactive sugar molecules. The CT and MRI produce black and white images, while the PET scans are in color. The PET scan is used to "watch" brain activity while patients are asked to perform certain tasks. (A new type of scan called the functional MRI, or fMRI, can also be used to watch the brain in action.)

Modern brain surgery has also added to our knowledge of the brain. Sometimes surgeons are even able to operate while the patients are awake, which allows them to ask the patients what they feel when different areas of the brain are touched. (The brain itself has no pain sensors, so this is not as bad as it sounds!)

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ACTIVITY #1.1 ***Use the Internet to compare types of scans***

Use Google image search and these keys words: CT brain scan, MRI brain scan, PET brain scan. Notice the similarities and differences between these types of images.

1) Which type of scan is most similar to an x-ray and gives only black and white images? ____
2) Which type of scan seems to be used more often for side views? ______
3) Which type of scan seems the least helpful for mapping out small brain parts? _____
4) If you were a doctor, which type of scan would you order if you knew your patient had metal implants in their body? _______ Why? ____
____
5) If you were a brain researcher and wanted to see what area of the brain was active when mathematical calculations were being done, which kind of scan would you use? _______
Why? ____

ACTIVITY #1.2 ***Videos about brain scans***

A special YouTube playlist has been set up for this book. Go to **www.YouTube.com/TheBase-mentWorkshop**, click on "Playlists." then find "Brain curriculum." The videos are arranged by chapter. The first few videos listed for chapter 1 are about these types of brain scans. You will see and hear very good explanations of how they work. (There are also some videos about Phineas Gage.)

ACTIVITY #1.3 ***Read more about Phineas Gage (if you want to)***

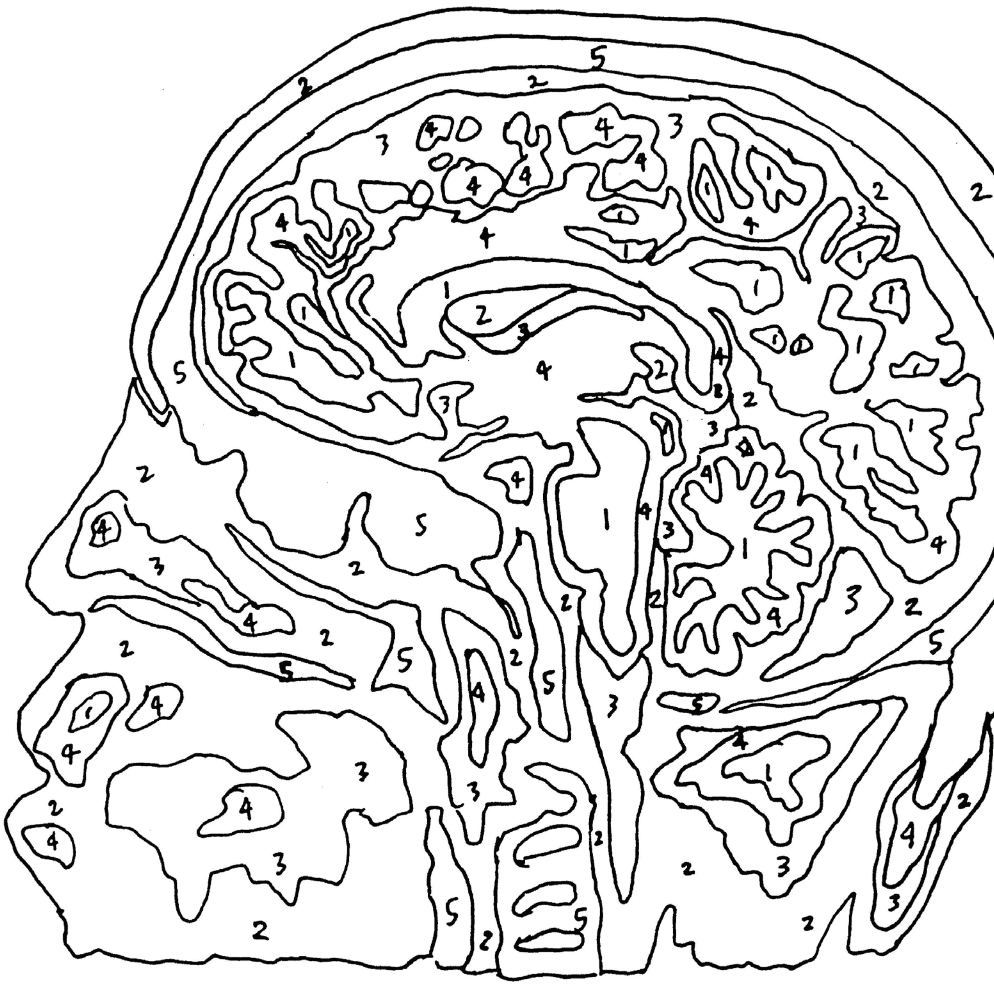
Phineas felt he was ready to go back to work only a few weeks after his accident. At first it looked like he would be able to pick up right where he left off, as the foreman of a blasting crew. His men soon discovered that he was hard to get along with and there were so many complaints about him that Phineas lost his job on the railway. While visiting his mother in New Hampshire, he was offered a job driving a stagecoach down in the country of Chile, in South America. He was promised he would not have to work with people, only horses. He got along just fine with animals, so he took the job and spent several years in Chile.

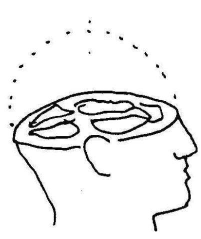
Meanwhile, Phineas' mother had moved to San Francisco. After Phineas lost his job in Chile, he went north to visit his mother. While in San Francisco, he began having seizures, which made him sick. His health started to deteriorate and eventually he had a seizure so severe that he died of it. He was buried in San Francisco, but several years later the doctor from Vermont asked to have Phineas' skull for medical research. Phineas' mother allowed the body to be dug up, and the head was removed by a surgeon. Along with the skull went the infamous tamping rod, which Phineas had taken with him every-where he went since the accident. Both Phineas' skull and his tamping rod are now in the collection of the Harvard Medical School in Boston. (You can see these artifacts in one of the videos on the playlist.)

ACTIVITY #1.4 *Color a PET scan*

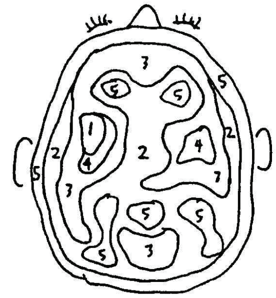
PET stands for Positron Emission Tomography. To prepare for a PET scan, the patient must drink a solution that has radioactive sugar molecules in it. Areas of the brain that are active use more sugar than areas that are inactive. The PET scanner can “see” the radioactive sugar as it is used by the brain and translates this into a color image. Areas of the brain that are highly active appear red; less active areas are blue or purple. (“Active” means more blood flow. The purple areas have the least blood flow and include areas of bone.) Use the numbers to color this PET image. Sharp colored pencils work best.

1 = red   2 = blue   3 = green   4 = yellow   5 = purple

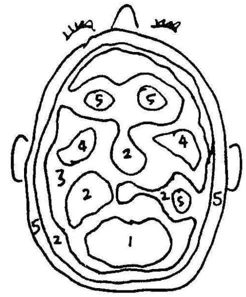




This is the section of the brain that is being scanned.



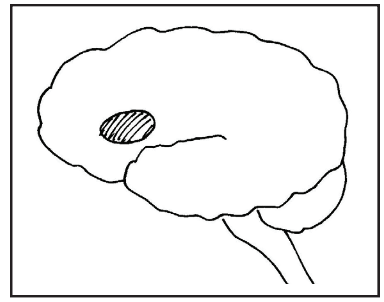
This is how the section looks when the patient’s eyes are closed.



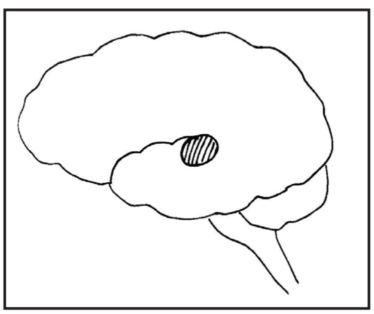
This is how the section looks when the patient’s eyes are open.

CHAPTER 1.5

MORE ABOUT BRAIN RESEARCH



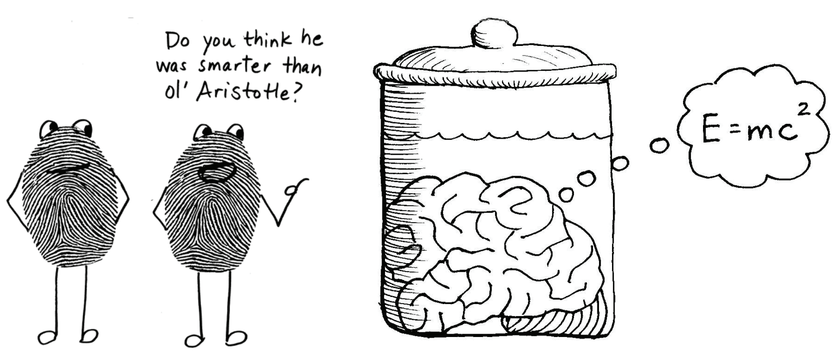
Starting in the late 1800s, doctors began to study patients with a type of brain injury called a ***stroke***. In a stroke, one or more blood vessels in the brain become blocked and blood cannot be delivered to the cells that are supplied by that vessel. The affected brain cells die from lack of oxygen. Strokes are very specific, and affect only one portion of the brain; this characteristic makes them extremely useful for finding out what certain areas of the brain do. A French surgeon named Paul Broca began studying patients that could not speak after having a stroke. He got permission from the patients to examine their brains after they died. Broca discovered visible damage to cells on the left side of the brain in the area of the temple, and concluded that this area must be critical to speech. This part of the brain has become known as ***Broca's area***.



In Germany, a doctor named Karl Wernicke *(VER-nih-kuh)* was also studying stroke patients. He had a number of patients who could talk, but could not understand speech. Examining these patients' brains, he found that they all had a diseased area on the left side above the ear. He guessed that this area of the brain must be vital to our ability to process the sounds and words we hear. Not surprisingly, this area of the brain has become known as ***Wernicke's area***.

As sad as brain injuries and diseases are, without them scientists would not have been able to discover how a healthy brain works. The good news is that the brain has amazing abilities to fix itself. Even in elderly patients, the brain often recovers from a stroke. Every year there is more and more evidence that the brain has more recuperative powers than was previously believed.

A fascinating story of brain research involves the brain of the famous scientist, Albert Einstein. After Einstein's death, the surgeon who performed the autopsy secretly removed Einstein's brain and kept it. No kidding—he really did! He kept it in a jar at his own personal lab, hoping that by examining it, he could find out what made Einstein so smart. Over the years, he sent small pieces of the brain to other researchers around the world. They all came up with different theories based on their research. Some said there was no difference. One researcher found that he had more glial cells (you'll learn about them in a future chapter). Others said that the area on the right side of the brain used for higher math concepts (the parietal lobe) was larger than normal. Or perhaps it was a thicker corpus callosum. We have theories, but we still don't know for sure what made Einstein's brain able to think the way it did.



ACTIVITY #1.5 *Find out more about MRI and PET*

Use Google search, or go to howstuffworks.com, to find out more about how MRI and PET scans work. (You can also use the videos from activity #1.2.) Answer the following questions about each.

MRI:

1) What does MRI stand for? ____
2) How big is an MRI machine? ____
3) Does it really have a big magnet in it? ________
4) Besides scanning the brain, what else is MRI good for? ________________________________
____
5) Briefly describe how an MRI machine produces an image: ______________________________
____
____
____
____
____
____
6) What is the difference between regular MRI and functional MRI? __________________________
____

PET:

1) What does PET stand for? ____
2) What must a person receive before getting a PET scan? ____________________________
3) What does the PET scan "see"? ____
4) Why is the PET scan in color and what do the colors represent? ____________________________
____
____
5) Besides brain imaging, what else is PET used for? ____________________________________
____

ACTIVITY #1.6 *Find out more about Einstein's brain*

If you find Einstein's brain a fascinating subject, there is more you can learn via the Internet. You can see actual pictures of his brain. (In fact, pieces of the brain were on public display in London in 2012.) Just use Google image search and key words "Einstein's brain." You might also want to read the Wikipedia article titled "Einstein's Brain."

There is also a short video documentary posted on the "Brain curriculum" playlist at **www.YouTube.com/TheBasementWorkshop**. Included in this video is an interview with Thomas Harvey, the doctor who removed and kept the brain. He kept parts of the brain in various jars that spent a good deal of time in the trunk of his car or in his basement. (Rumor has it that he also removed Einstein's eyes, and gave them to Einstein's eye doctor. The eyes are now reportedly in safe deposit box in New Jersey.)

ACTIVITY #1.7 *Watch a few short videos on Broca's area and Wernicke's area*

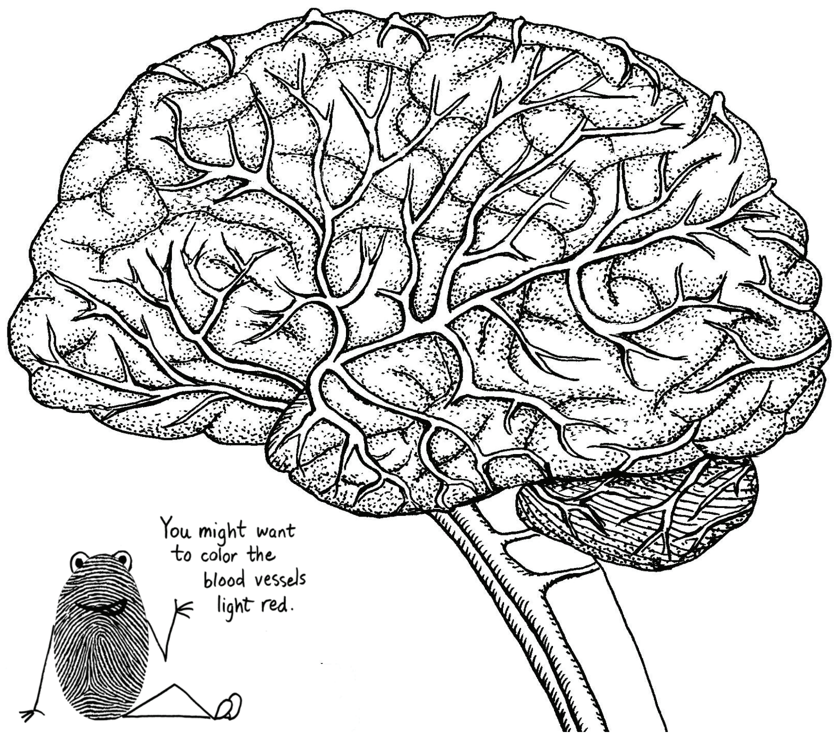
Go to the Brain curriculum playlist to see some video clips about these areas. (The exact videos available might change over time, as videos are added or removed from YouTube.)

CHAPTER 2

BASIC BRAIN ANATOMY

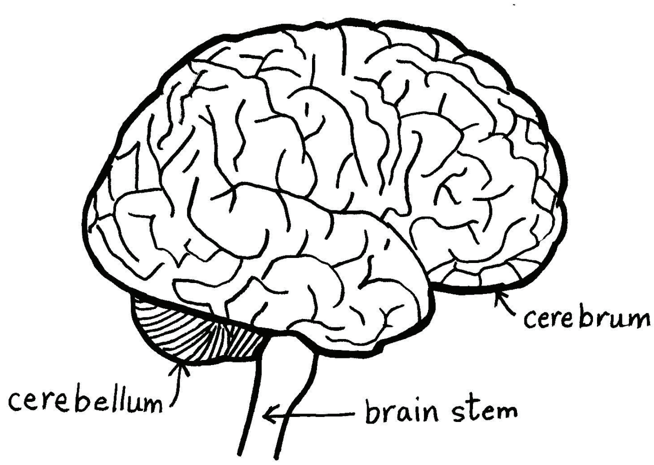
Your brain fills up most of your head and weighs about 1.5 kg (3 pounds). The brain needs a lot of blood, so it sits on top of some very large blood vessels, almost like a ball balanced on top of a fountain. It receives 35 liters (33 quarts) of blood every hour! The blood brings oxygen and sugar to the brain and carries away waste products and carbon dioxide. The brain uses more energy than any other organ of the body, consuming 40% of the oxygen and sugar you take in.

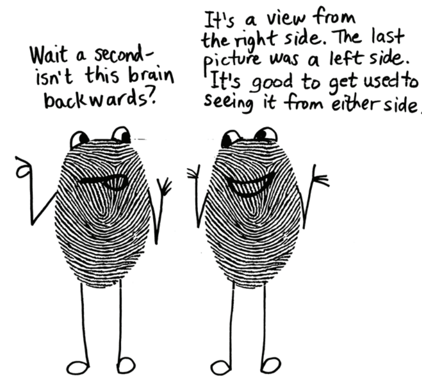
The large blood vessels branch off into smaller and smaller vessels, down to microscopic vessels called ***capillaries***. The capillaries form a fine network all through the brain, making sure that every cell gets nourishment.



You can see that the brain looks wrinkled and folded. There is a good reason for this. The surface layer (***cortex***) of the brain is larger than it appears. If you peeled it off the brain and laid it out flat, it would cover an area about the size of a kitchen table. Imagine the cortex as a tablecloth that has been crumpled up to fit inside your head. The more wrinkles there are, the more brain cortex there is. (In general, you can tell how intelligent an animal is by looking at how wrinkly its brain is. Wrinkles are a better guideline for intelligence than size is.)

Inside the skull, the brain is surrounded by a layer of watery fluid which cushions it and protects it from bumps and bangs. The fluid also helps to nourish the cells, delivering nutrients to them. Although watery fluid isn't as exciting to learn about as the brain itself, it does deserve to be mentioned because without this fluid, you would be risking brain injury every time you went out to play. After the fluid bathes the brain, it flows down the middle of the spinal column, bathing all the spinal nerves. Eventually the fluid exits at the bottom of the spinal cord and is reabsorbed by other body tissues. The brain is constantly making new fluid at the rate of about a spoonful every hour. As we'll learn in a later chapter, the proper name for this fluid is ***cerebrospinal fluid***.



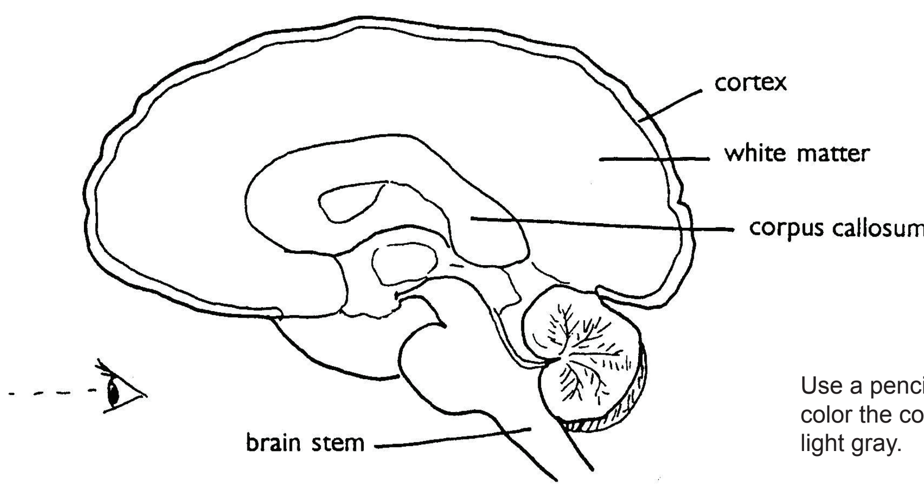


There are three main sections of the brain. The largest section, the top part, is called the ***cerebrum***. (Most people pronounce it like "*sah-REE-brum*" but the dictionary says that "*SARE-eh-brum*" is also correct.) This is the part that you consider your "real" brain. This is where your thinking and feeling take place. It is also the part that commands your muscles to move and processes information from your eyes and ears.

The little wrinkly blob under the cerebrum is called the ***cerebellum*** *(sare-eh-BELL-um)*. It's almost like a separate brain. Its name means "little brain." This part of your brain is in charge of coordinating balance and movement. Without your cerebellum you would fall over if you tried to walk. You need it to help you do things like throwing a ball into a hoop or shooting at a target. (An interesting fact about the cerebellum is that it is the fastest growing part of the brain and reaches almost adult size by the time a child is two years old.)

The stem-like thing sticking out the bottom is called the ***brain stem***. It performs the bodily functions you take for granted, such as your breathing and the beating of your heart.

Now let's split the brain open and take a look at the inside.

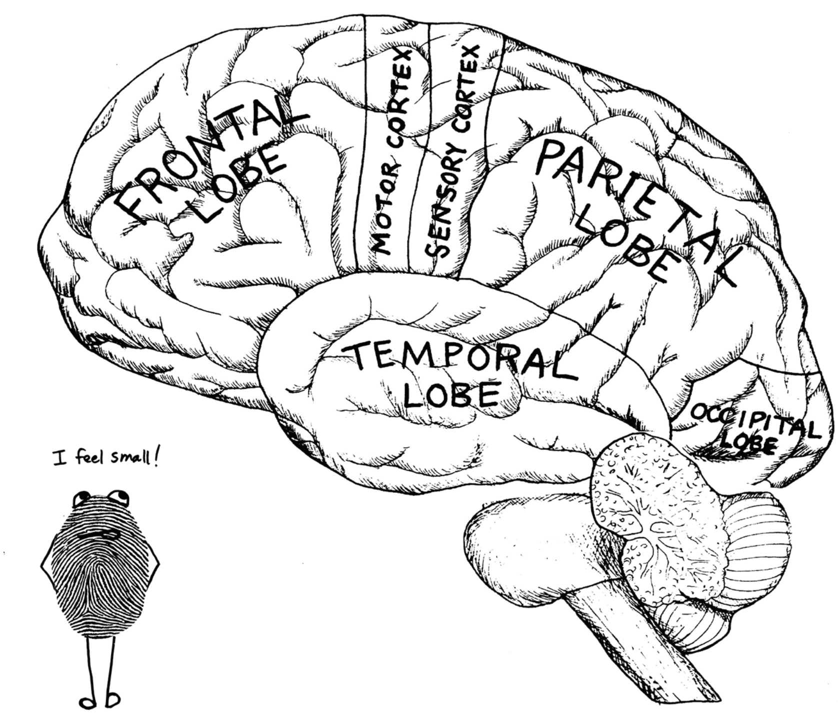


Use a pencil to color the cortex light gray.

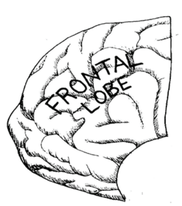
In this diagram, you can see the cortex that we mentioned when we discussed why the brain is wrinkly. The cortex (which doesn't look particularly wrinkly in this picture) is about as thick as a piece of corrugated cardboard. This is where thinking takes place. The cortex is sometimes called our "gray matter" because it does look light gray in color. Underneath the gray matter is a thick section called "white matter." We'll learn more about the white matter when we learn about individual brain cells and what they do.

The sideways C-shaped thing in the middle, the ***corpus callosum***, is a connecting bridge between the right and left sides of the brain. If you look at the outside of the brain you can see that there is a split down the middle. The cerebrum is in two halves, connected to each other by the corpus callosum. It is believed that the thicker the corpus callosum is, the better the connection between the two hemispheres. (Some of the researchers who examined Einstein's brain say that his corpus callosum was extremely thick.) We'll learn more about the left and right sides of the brain in the next chapter.

Now let's see how the cerebrum can be broken apart into six distinct areas. We know what and where these areas are because of the brain research techniques we read about in chapter 1. Of course, a real brain doesn't have any lines on it. These are imaginary lines, similar to the lines between states or countries on a map. A brain surgeon must know where these areas are without any lines to help him.



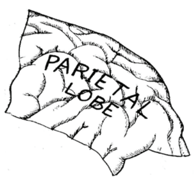
So what do these six parts do? The name of the sensory cortex might give you a hint about that one. But what about the parietal or the occipital? Here is a brief description of each part of the cerebrum and what it does:



FRONTAL LOBE: Located in the front of your head, behind your forehead (thus its name), this is the area of your brain that you think of when you think of your "brain." (Isn't it funny that your brain can think about itself thinking?) The frontal lobe is where you make decisions and do mental calculations. When you play chess, you give your frontal lobe a workout. The frontal lobe is responsible for monitoring your behavior and learning social skills that you need in order to get along with other people. The famous example of Phineas Gage shows how damage to the frontal lobe can result in a change of personality. Before the accident Phineas was responsible, polite, and good with people. After the accident he was irresponsible, rude, and terrible with people. The frontal lobe has connections to other parts of the brain. For example, it gives directions to the motor cortex when you decide that you want to move your arms or legs.

MOTOR CORTEX: Right next to the frontal lobe is the thin strip of cortex that sends signals to your muscles telling them to move (or to stop moving). Your frontal lobe thinks of your chess move, then sends a signal to the motor cortex, which in turn sends signals to the muscles in your arm and hand, causing them to pick up your chess piece and move it to another square. (Oddly enough, the right side of the cortex is connected to the left side of the body, and the left side of the cortex is connected to the right side of the body.)

SENSORY CORTEX: This thin strip is connected to all parts of your body and receives messages about things you feel. If you get a sudden pain in your wrist, the pain sensation is received in the brain by the sensory cortex. The sensory cortex can relay this information on to your frontal lobe so that you can think about why your wrist hurts and possibly take steps to fix whatever is causing the pain. The sensory cortex has two sides, each one matching up to the opposite side of the body. So, for example, the signals from your right hand go to the left side of the cortex. Some parts of the body, such as your fingertips and face, get a much larger section of the cortex devoted to them. These parts need more sensing nerves than parts such as the back or the legs.



PARIETAL *(par-EYE-it-al)* LOBE: This area of the brain is the most mysterious one. Scientists still don't know everything the parietal lobe does. Its main job seems to be keeping track of where your body is and what it is doing. If you close your eyes, you still know what your arms are doing. You can bring your hands together without looking because of your parietal lobe. It also seems to keep track of all the objects in your environment, and knows "which end is up." For example, you know which end of a pencil is used for writing, even if the pencil is upside down. This may seem a bit obvious, or even silly, but this function of the brain is very important. Your parietal lobe takes input signals from your body parts and keeps track of them, making sense of it all and then relaying this information to your frontal lobe. The parietal lobe works with the cerebellum and the inner ear to give you your sense of balance.

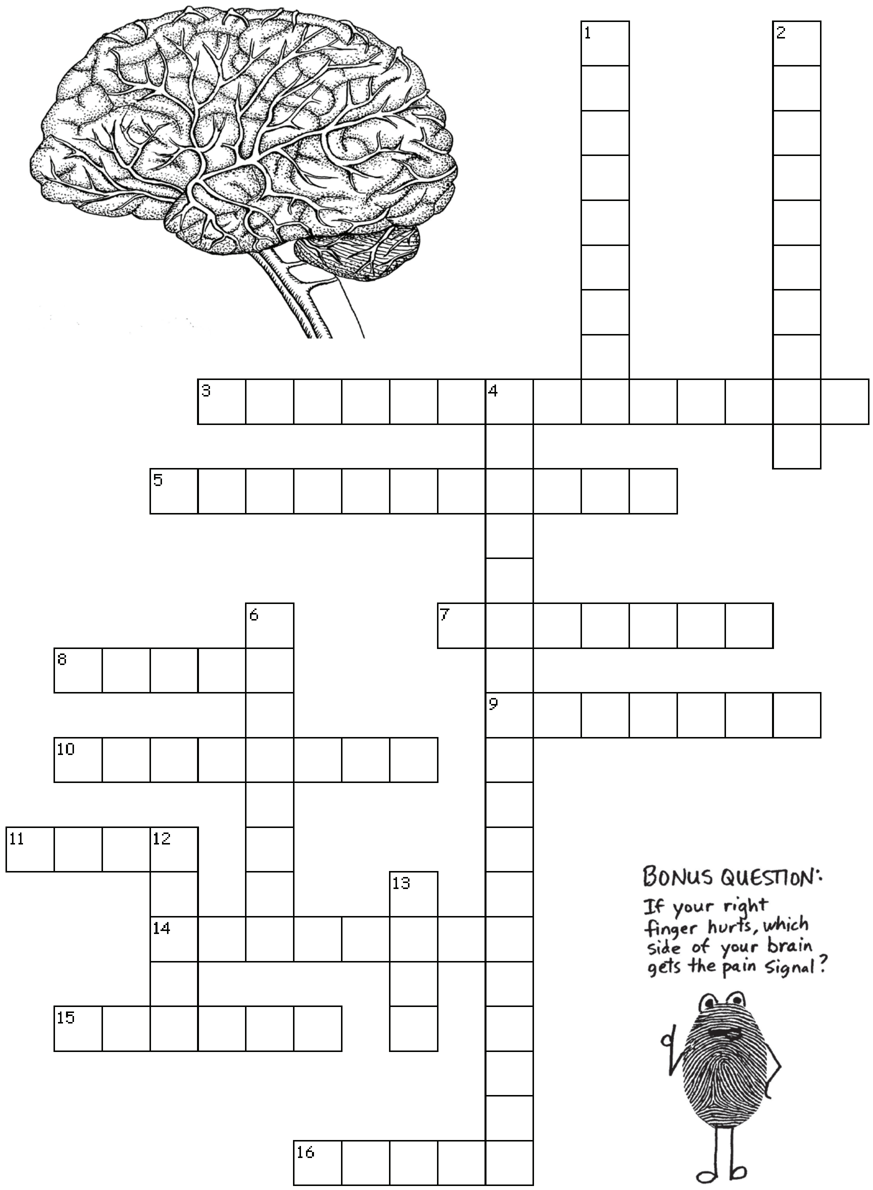
OCCIPITAL (*ock-SIP-it-al)* LOBE: This area, located at the back of your head, is where the input from your eyes gets processed. It may seem strange, but the nerves from the eyes travel all the way to the back of the brain. Not only that, but the nerves from the eyes cross over in the middle so that the left eye connects to the right side of the brain and the right eye connects to the left side of the brain. To further complicate things, the images arrive at the occipital lobe upside down! The occipital lobe has to make sense out of all the upside-down images that come from your eyes. It turns everything right side up and figures out what you are looking at. Your eyes only do half the job of seeing. The occipital lobe has to finish the job.

TEMPORAL LOBE: This area is on the side of the head, behind your ears and your temples. (The temples are the sides of your forehead.) The temporal lobe is in charge of quite a few things, including your ears and nose. Your ability to speak and to understand speech is located in the temporal lobe. When you talk, you are using your temporal lobe to construct a sentence that makes sense. The temporal lobe has connections to the frontal lobe and the motor cortex so that you can decide what to say, then send signals to the muscles in your mouth and throat. Your sense of smell and your memory of smells are also located in the temporal lobe. The temporal lobe is very close to the inner part of your brain where memories are stored.

ACTIVITY #2.1 ***A crossword puzzle about the brain***

ACROSS:
3) This "firm body" is the bridge between the two hemispheres.
5) Tiny blood vessels
7) This lobe is the one you use to make decisions
8) The ____ matter is the interior of the cerebrum. It is much thicker than the gray matter.
9) The _____ cortex receives incoming signlas from the senses.
10) The ___ lobe keeps track of where your body is in 3D space.
11) The brain ____ contains many reflexes and automatic functions like breathing.
14) The ___ lobe has many functions including smelling, hearing, speaking and listening.
15) The outer layer of the cerebrum is often called the ___.
16) This fluid brings oxygen to the brain.

DOWN:
1) This lobe is connected to your eyes and is responsible for interpreting visual signals.
2) This means "little brain;" it coordinates movement and balance.
4) This fluid is in the "empty spaces" in the brain and helps to cushion and protect it.
6) This is the large top part of the brain. It is divided into both hemispheres and lobes.
12) The ___ cortex sends out signals to the muscles.
13) The ___ matter is the outer layer (the cortex) of the cerebrum.



ACTIVITY #2.2 ***What brain parts are used for these activities?***

For each of the activities described below, list the lobes of the brain that you would use and what each one would be used for. The first one is done for you as an example.

1) Brushing your teeth:
FRONTAL LOBE: decides to brush teeth and sends signals to motor cortex
MOTOR CORTEX: tells muscles to move toothbrush around in the mouth
SENSORY CORTEX: Feels the brush in your hand, feels the scrubbing on your gums and teeth
PARIETAL LOBE: Senses that the hands are raised to the mouth, also keeps you balanced
OCCIPITAL LOBE: Makes sense of what your eyes are seeing in the mirror
TEMPORAL LOBE: Smells the toothpaste

2) Playing the piano

FRONTAL LOBE: ______________________________

MOTOR CORTEX: ______________________________

SENSORY CORTEX: ______________________________

PARIETAL LOBE: ______________________________

OCCIPITAL LOBE: ______________________________

TEMPORAL LOBE: ______________________________

3) Riding a bicycle

FRONTAL LOBE: ______________________________

MOTOR CORTEX: ______________________________

SENSORY CORTEX: ______________________________

PARIETAL LOBE: ______________________________

OCCIPITAL LOBE: ______________________________

TEMPORAL LOBE: ______________________________

4) Talking on the telephone

FRONTAL LOBE: ______________________________

MOTOR CORTEX: ______________________________

SENSORY CORTEX: ______________________________

PARIETAL LOBE: ______________________________

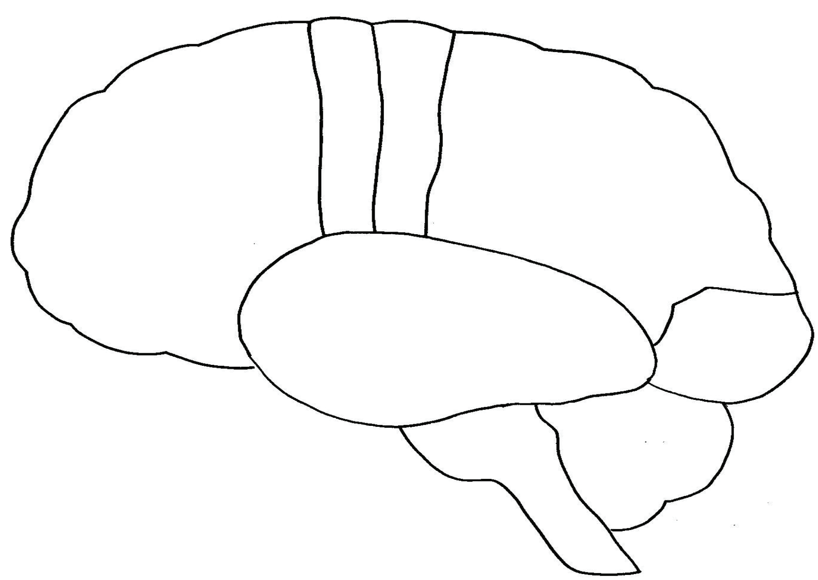
OCCIPITAL LOBE: ______________________________

TEMPORAL LOBE: ______________________________

ACTIVITY #2.3 ***Color a "map" of the brain***

Fill in a color for each square of the key, then color the corresponding brain part that color.

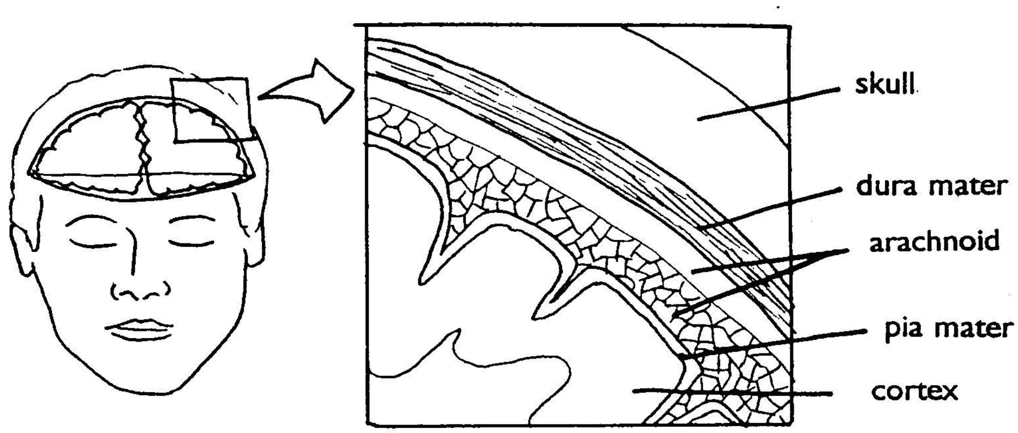
- ☐ FRONTAL LOBE
- ☐ MOTOR CORTEX
- ☐ SENSORY CORTEX
- ☐ PARIETAL LOBE
- ☐ OCCIPITAL LOBE
- ☐ CEREBELLUM
- ☐ BRAIN STEM
- ☐ TEMPORAL LOBE



CHAPTER 2.5

MORE ABOUT BASIC BRAIN ANATOMY

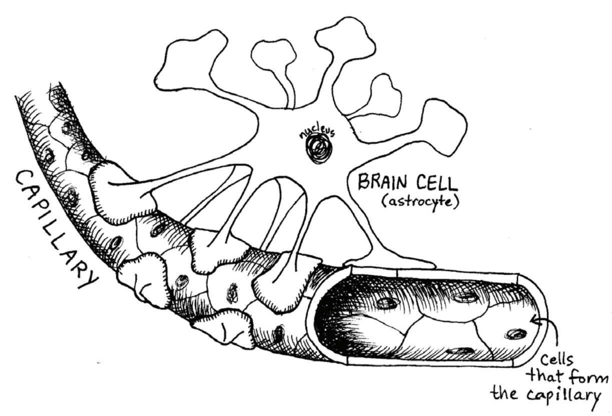
Let's take a closer look at the tissues and fluid that surround the brain. The tissues are called the ***meninges*** *(men-IN-juz)* and are made up of three distinct layers. The first layer, right under the skull, is called the ***dura mater***. "Dura" means "hard" and "mater" means "mother." (Can you think of why a protective layer might be called a mother?) The texture of this layer is leathery and tough and is attached to the skull. (Moms have to be tough sometimes!)

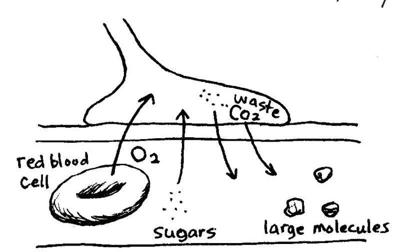


The second layer is called the ***arachnoid*** *(ah-RACK-noid)* layer. You might notice that this word is close to the scientific name for spiders: the arachnids. The arachnoid layer of the brain was given this name because under the microscope it looks a bit like a spider web. It is inside the arachnoid layer that the protective cerebrospinal fluid flows.

The third layer, called the ***pia mater,*** is delicate and soft ("pia" means soft) and it attaches to the surface of the brain, following every wrinkle and bump. These three layers work together to cushion the brain and protect if from all the bangs and bumps that life inevitably brings.

Another important safety feature of the brain is called the ***blood-brain barrier (BBB)***. The tiny blood vessels in the brain (the capillaries) are close enough to the brain cells that oxygen and sugar can pass from the blood into the cells, and carbon dioxide and waste molecules can pass out of the cells and be carried away by the blood. (The brain cell in the picture is really weird-looking, isn't it? More about brain cells in chapter 5.) The cells that make up the capillaries in the brain are joined together very tightly so that only very small molecules can get in or out. This protects the brain from potentially harmful substances. Bacteria are huge compared to nutrient molecules, so they hardly ever get into the brain. If bacteria do get in, this poses a problem for doctors because the barrier keeps most antibiotic molecules out. (A sugar called mannitol is often used to temporarily loosen up the junctions between the cells and allow larger molecules, such as antibiotics, to get in.)

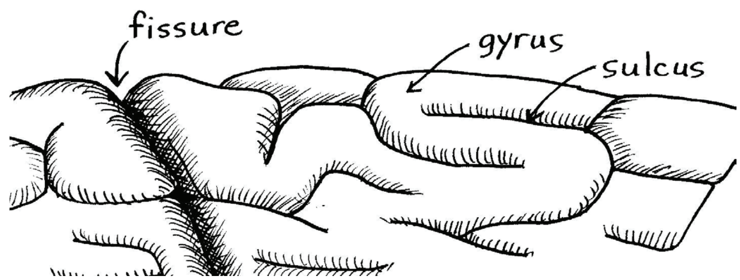




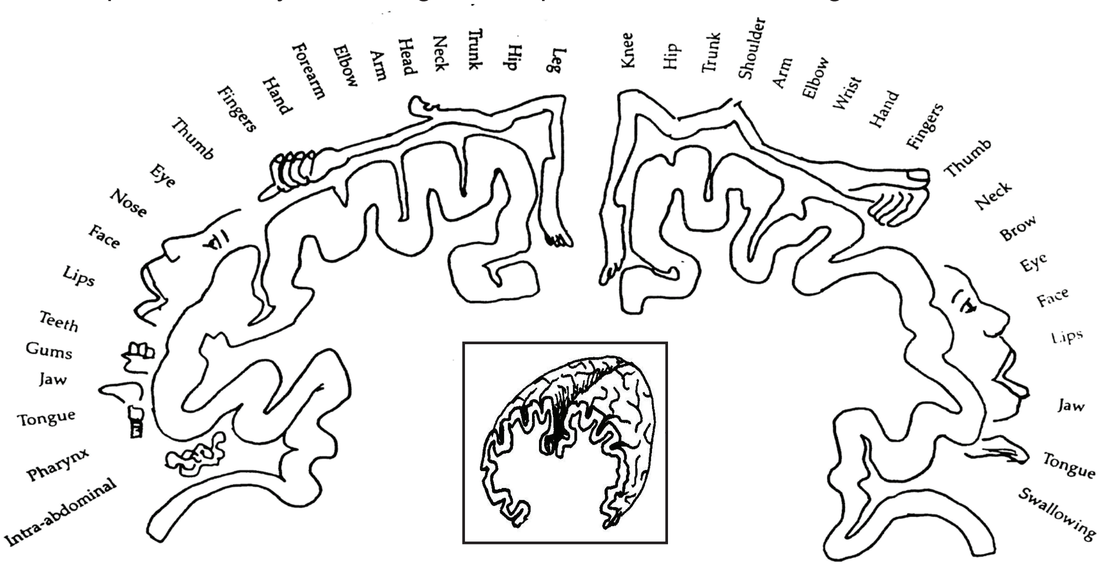
The red cell stays outside;
just the oxygen goes in.

The brain has two important fluids: blood and ***cerebrospinal fluid*** (***CSF***). Both help to bring nutrients to brain cells, but blood is the leader in this task. Both help to clear out waste products produced by brain cells, but the CSF seems to take the lead in clean-up. The CSF is especially active while you sleep, flushing out all the waste products produced by the brain cells while you are awake. The CSF moves out of the brain and down the spinal column and is finally reabsorbed into the blood. The blood then goes to the kidneys and liver which clean the blood and get rid of wastes. (Sorry to use such a general word—"wastes"—but discussing exactly what these wastes are made of is beyond the scope of this book. It's complicated.)

For those of you who like to know the correct names for things, here are a few more correct names for brain parts. Each wrinkly bump is a ***gyrus***. *(JIE-rus)* The valley in between is called the ***sulcus***. A split between lobes of the brain is called a ***fissure***, which is just a fancy name for "crack."



Now let's take a closer look at the sensory cortex. If you laid it out in a semi-circle and wrote down what each part of it did, you would get a "map" that looks something like this:



Scientists call this diagram the ***homunculus***, meaning "little man." What it shows you is how much of the cortex (and which parts) are devoted to certain parts of the body. Your back doesn't need to be as sensitive as your fingertips, so less of the cortex is devoted to the back. You can see that the face takes up almost as much space as the rest of the body does.

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ACTIVITY #2.4 ***Measure the length of the sensory cortex***

You will notice how wrinkly the cortex is. Remember that there is a reason that the cortex is wrinkly-- it's so that a large surface area can be scrunched into a small space. Use a piece of string to measure the cortex in this diagram. Lay the string along the cortex, following all the twists and turns. Put a mark on the string where it reaches the end of the cortex. Then pull the string out to its full length and measure it.

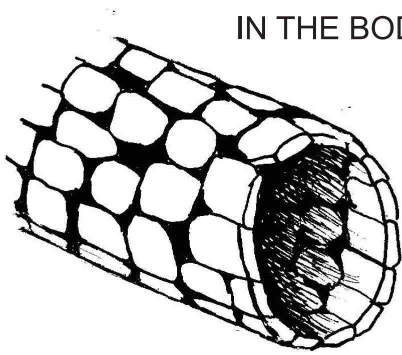
The cortex on the left is _____ centimeters. The cortex on the right is _____ centimeters.

ACTIVITY #2.5 *Read more about the blood-brain barrier*

The discovery of the blood-brain barrier (abbreviated as BBB) goes back to the late 1800s when Paul Ehrlich, (famous for inventing many of the stains that are used in preparation of microscope slides), discovered that when blue dye was injected into a lab animal's body, it stained all the tissues in the body except for the brain. This suggested that something was not allowing the dye to enter the brain. Then it was found that if the dye was injected into the cerebrospinal fluid, the brain would be dyed but nothing else in the body would be. This suggested that something was not allowing the dye to exit the brain. There seemed to be a barrier that would not allow chemicals to pass either into or out of the brain.

With the invention of the electron microscope in the 1960's, researchers could take a close-up look at the cellular structure of the capillaries in the brain. The capillaries are made up of individual cells, just like any other organ of the body. In the rest of the body, the cells that make up the capillary walls seem to be spaced far enough apart that almost any size or type of molecule can get in or out.

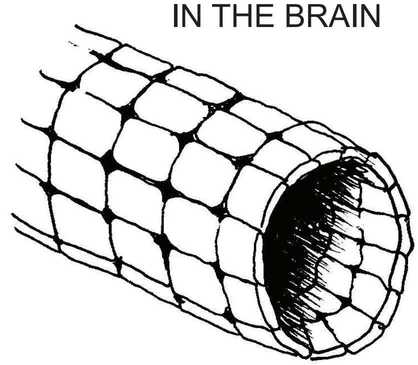
IN THE BODY



This drawing represents capillaries in regular body tissue. The cells have large gaps between them that allow molecules to go in and out easily.

NOTE: This drawing is not to scale. The cells have been simplified to make it easier to see the gaps. Real capillary cells are not square.

IN THE BRAIN



This drawing represents capillaries in the brain. The cells are squeezed tightly together so that the spaces in between are very small.

NOTE: As with the other drawing, the cells are not to scale, and have been simplified.

In brain capillaries, however, the cells are more tightly packed together. Most molecules are too big to squeeze through the gaps. The BBB blocks most molecules from crossing, except those that the brain needs (or needs to get rid of): oxygen, carbon dioxide, hormones, sugars and amino acids. Small molecules such as alcohol (ethanol) can also pass throught the BBB. The brain does not need alcohol and yet it can get into the brain. (When too much alcohol passes into the central nervous system we call this "intoxication.")

About 98 percent of all medical drugs cannot get past the BBB. This makes it very difficult for doctors to treat brain problems, especially infections. To treat brain infections, doctors must first give the patient a drug that causes the capillary cells to loosen up. Fortunately, the BBB does an excellent job of preventing bacteria and viruses from entering the brain in the first place, so brain infections are extremely rare.

Certain diseases and conditions can weaken the BBB and increase the gaps so that larger molecules can squeeze through. The meninges are on the outside of the BBB so they are susceptible to infection. If the meninges are inflamed, the BBB is disrupted. High blood pressure can weaken the barrier, also. Imagine the blood flowing through the tiny capillaries putting so much pressure on the capillary walls, that little gaps are opened up, allowing larger molecules to leak through. Diseases such as Alzheimer's and multiple sclerosis (MS) also disrupt the BBB.

There are a few places in the brain where the blood is sampled to see how much of a certain substance is in it. The brain is the master controller of bodily secretions such as hormones, and it must maintain a constant balance of these chemicals in the blood. As you might guess, the "blood sampling areas" in the brain have a weak barrier and allow everything to pass through.

ACTIVITY #2.6 ***Look at animal brains and compare them to the human brain***

Check out **brainmuseum.org**. Click on “brain sections” in the menu bar on the left. Then scroll down and click on the name of any animal to see a picture (photograph) of its brain. The charts will show you different views of the brain: left, right, bottom, top.

How do the sizes of the cerebrums compare to the total brain size? Remember that the cerebrum is where thinking takes place and wrinkles indicate a large surface area crunched into a small space. No wrinkles means less surface area, and, therefore, less thinking power. How does a rabbit brain compare to a pig? Which one would be capable of learning tricks? Compare the manatee brain with the dolphin brain. Both are sea mammals, but which one is probably smarter? Can you spot any differences between a human brain and a chimp brain? Notice in many of the animal brains that there is a large bulbous part coming out in front of the frontal lobe. These are sensory areas, likely connected to the nose. How much of the lion’s brain is devoted to the sense of smell?

ACTIVITY #2.7 ***Some brain anatomy videos***

Go to **www.YouTube.com/TheBasementWorkshop**, click on “Playlists” then on “Brain Curriculum.” There are a few videos that go with this chapter. (They might contain some brain parts we won’t cover until future chapters, but they will also review much of what you’ve just read about.)

PANIC PREVENTION: You might hear some new vocabulary words in these videos. Don’t panic! Just focus on listening for the words you’ve learned so far. Then, watch the video again, this time listening for new words and trying to figure out what they mean. (“Saggital view” means splitting something into left and right sides, “posterior” means “back,” and “anterior” means “front.”)

ACTIVITY #2.8 ***Cerebrospinal Greek and Latin***

You have noticed that most medical words are taken from either Latin or Greek. It seems like scientists are always trying to make things harder for students! Why can’t they just say “membrane” and not “meninges”? Why does “little brain” have to be “cerebellum”? The reason for this is that scientists have tried to choose names that are as “neutral” as possible and don’t favor any one modern European language, such as English, French, German or Spanish. Basing science words on an extinct language also guarantees that the words won’t change their meaning over time. Modern Greek isn’t the same as ancient Greek. The more a language is spoken, the more it changes.

This word puzzle doesn’t need much explanation. Just figure out which of the Latin or Greek words on the right matches each definition on the left. For this exercise, we won’t bother sorting out which are Latin and which are Greek. If you want to do that, just look the words up in a dictionary.

1) Hard: __ __ __ __
2) Soft: __ __ __
3) Spider-like: __ __ __ __ __ __ __ __ __
4) Crack: __ __ __ __ __ __ __
5) Body: __ __ __ __ __ __
6) Firm: __ __ __ __ __ __ __ __
7) Against: __ __ __ __
8) Brain: __ __ __ __ __ __ __ __
9) Little brain: __ __ __ __ __ __ __ __ __ __
10) Ring or circle: __ __ __ __ __
11) Furrow, valley or groove: __ __ __ __ __ __
12) Pertaining to the eye: __ __ __ __ __ __ __ __ __
13) Bark, covering, or shell: __ __ __ __ __ __
14) Membranes: __ __ __ __ __ __ __ __
15) Pertaining to walls: __ __ __ __ __ __ __ __

ANTI
ARACHNOID
CALLOSUM
CEREBELLUM
CEREBRUM
CORPUS
CORTEX
DURA
FISSURE
GYRUS
MENINGES
OCCIPITAL
PARIETAL
PIA
SULCUS