Investigation 3.13

3.13A: The Brain
3.13B: Normal or Abnormal?

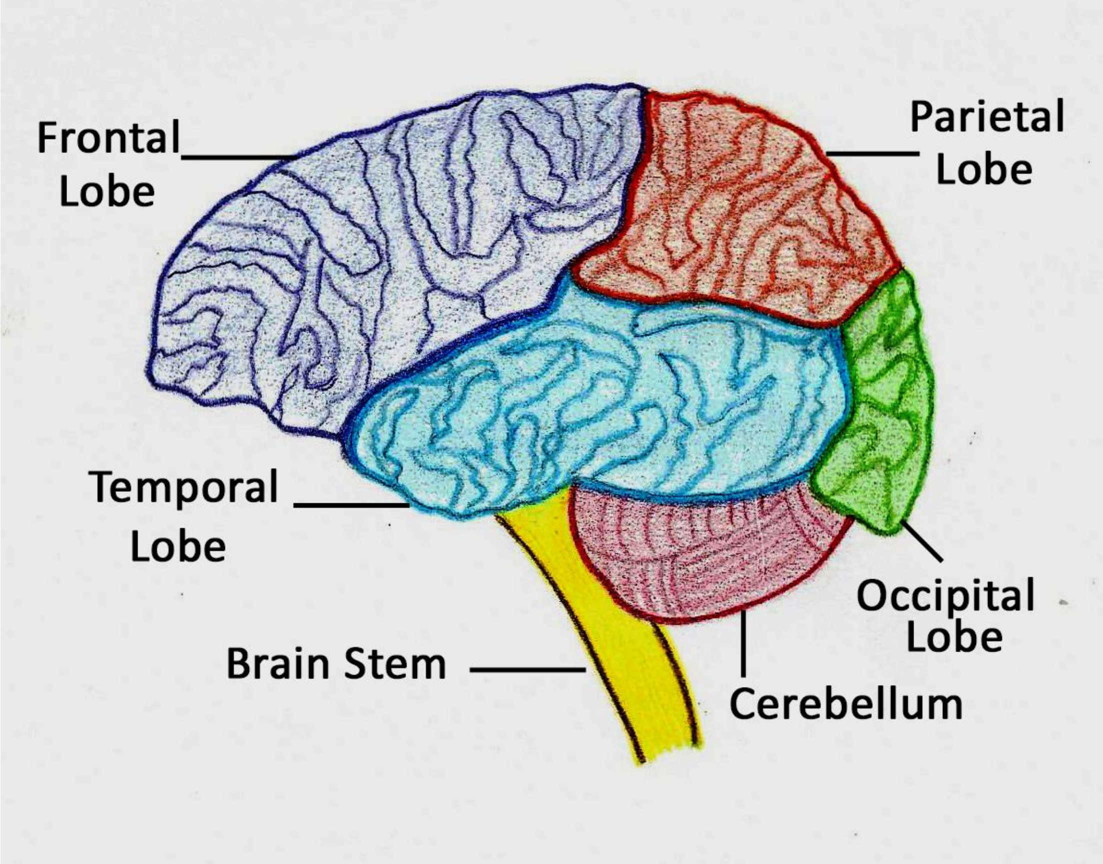
Investigation

3.13A: The Brain

In the previous chapter your patient’s pupils were dilated and did not respond to light as she lay on the basketball court. You learned that this finding did not represent an injury to her eyes. Instead, it indicated that the patient’s brain was not responding normally to the stimulation of a bright light shone into her eyes. A person’s eyes and brain must work together to provide them the ability to see the wonderful world around them because vision requires much more than simply the detection of light. The brain must process the patterns of light that fall on the retina to create a mental model and an understanding of what that image represents. That task constitutes an amazingly complex achievement.

Anatomists study the structure of the human, starting with the large structures we can easily see, and going down to the structures so tiny that we can only examine them with the aid of an electron microscope. Anatomists who specialize in studying the brain we call **Neuroanatomists.**

You probably know very well the meaning of the word “**gross**.” Actually that word has several different meanings: the one you do not want applied to anything you do or say, one that often refers to the total salary one gets paid before any deductions, and in medical science a third meaning that indicates a structure big enough to be seen and studied simply by looking at it. Below you will find a drawing of the gross anatomy of the brain.



This view of the brain shows inside the skull of a head from the left side (**profile)** with the nose pointing off to your left. Later you will see another view of the brain looking down on it, as if you were on a ladder looking down from on high at a person standing directly below you. From that position you can see that the human brain is divided down the middle into left and right halves. The neuroanatomist would call each half a **hemisphere** (hemi- meaning half and –sphere meaning a ball). We each have a left hemisphere and a right hemisphere of our brain inside our head.

The neuroanatomist further divides the human brain into four sections, called **lobes**, in each hemisphere. These four lobes all have a similar surface appearance, almost looking like they are composed of a ball of heavy smooth rope all tangled up. That tangled rope surface they call the **cerebral cortex,** and they divide it into the **frontal, parietal, temporal, and occipital lobes.** An additional region of the brain has different surface appearance as if made up of a ball of much smaller rope, the **cerebellum.**

If you study the anatomy of an organ like the heart, you can look at its structure and almost immediately understand what it does and how it functions to pump blood. The brain does not cooperate at all with that approach to understanding how it works because this organ does not perform a **mechanical** function. The cells that do the work inside the brain use **electro-chemical** processes, not mechanical. So we get very little understanding of how the brain works by studying its outward appearance, which we have now learned to call the brain's **gross anatomy**. Nonetheless, these diagrams of the brain have given you a basic view of the brain's anatomy.

We can dig a little deeper into this topic by trying to categorize the role each lobe seems to play in the many jobs our brain performs. As we do that, you probably should not totally believe the descriptions you will read. The more we know about the brain, the more we believe that no two brains think completely alike.

We know clearly that very young children who suffer some form of head injury that destroys a particular area of the brain, surprisingly appear to grow older with amazingly normal brain function. Physicians common describe this ability of the brain by the term "**neural plasticity**," suggesting that the brain's **neurons** have the ability to "learn" and "adapt" to meet the individual's needs regardless of where they sit inside the brain. In other words, when we say a particular section of the brain does a specific task, we may find normal individuals with a different location for that brain activity.

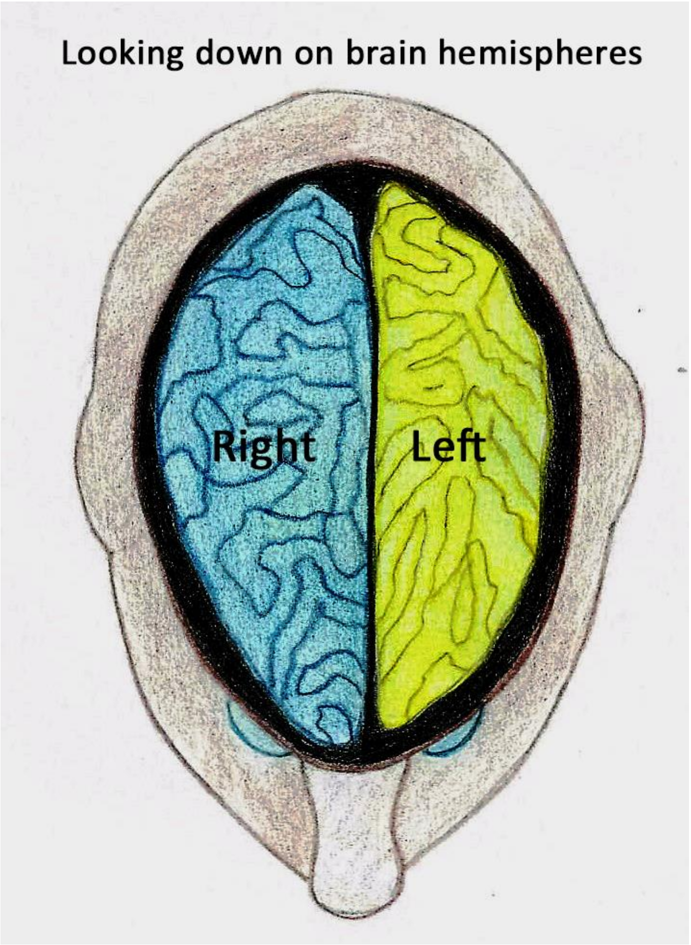
The traditional way of teaching students about the brain consisted of assigning names to all the various regions of turns and twists in the brain's surface. Next, the student learned names for all the structures inside the brain seen by looking at photographs of stained, cross-sectional slices through the brain. Students could easily find themselves memorizing bizarre sounding words that name dozens upon dozens of shapes and features of the brain's gross anatomy. Finally, students memorized the apparent roles these structures play in the workings of the brain, as identified by the observations of scientists over centuries of the deficits exhibited by people who have injuries to those parts of their brain.

More recently, sophisticated scanners using **radioisotopes** have allowed scientists to observe increased activity in various parts of the brain in living research subjects as they think about various topics or questions, so that researchers can increase our knowledge of where various mental activities appear to take place inside this organ. This quest has value in allowing **neurologists** or **neurosurgeons** to know where to look for brain damage when faced with a patient with a specific constellation of symptoms, but this approach probably will not give you any important insight how your brain does all the amazing things it can do. So, in this workbook we are not going to burden you with basal ganglia, the medulla oblongata, the cingulate gyrus, or the telodien-cephalic sulcus. I hope you will forgive us.

Before we move on, we do want you to have an awareness that a very common cause of death and permanent disability, especially in older individuals, comes from a blockage of an artery in the brain or a rupture of a blood vessel in the brain that causes a region of the brain to stop working. We call such an event a **stroke**. Fortunately, if we recognize a stroke and get the victim to a stoke-center hospital quickly, the effects of the stroke can often be reversed. If you are with someone who has a rapid loss of speech, or loss of sensation or movement on one side of their body, think immediately that they may have had a stroke and do your best to get them transported to a hospital immediately. Getting treatment quickly makes a huge difference in the **outcome** of such an event. Everyone should have the ability to recognize the symptoms of a stroke so they can respond correctly to such an emergency. Your recognition of these symptoms and prompt response could save the life of someone you love.

Right-Brain Functions

- **Art awareness**
- **Creativity**
- **Holistic thought**
- **Imagination**
- **Insight**
- **Intuition**
- **Left-hand control**
- **3-D forms**


Looking down on brain hemispheres

Left-Brain Functions

- Analytic thought
- Language
- Logic
- Number skills
- Reasoning
- Right-hand control
- Science & Math
- Writing

Put on Your Seat Belt for a Whirlwind Tour of the Lobes of the Brain

We are not going deeply into brain anatomy, but we want you to have the basics.

As its name suggests, the **frontal lobe** sits right behind your forehead. We often say one's personality emanates from the frontal lobe. Your emotions, your determination, your passions, your hopes appear to live in this lobe. Neurosurgeons, who treat patients who have injured their frontal lobes in an automobile accident, notice that such individuals often appear to recover fully by all standard objective nervous system examination criteria, and yet they no longer seem to interact with others as they did before their injury or achieve the goals in live everyone expected of them. We, therefore, see the frontal lobe as playing a **modulating** role in the subtle, unique skills and traits that make us who we are.

The **parietal lobes** are located on the upper sides of your head above your ears in both hemispheres. The parietal lobes seem to have an invisible, distorted diagram of your entire body drawn on its surface, such that stimulation of any point in that part of the brain evokes a sensation of something touching that part of your body. These distorted diagrams we call a **cortical homunculus.** Actually we have two of these neurologic maps across each parietal lobe, one associated with **sensation** and one **motor** (muscle movement).

So think of the parietal lobe of the body as the highest level of sensory and motor awareness of all your body's sensations and movement. The left side of the body maps to the right side of the brain, and the right side of the body maps to the left hemisphere of the brain. This apparent cross wiring of the brain occurs consistently throughout the animal kingdom, and scientists have put forward a variety of theories for this crossed up wiring. You can think up your own theory if you like.

The **temporal lobe** manages your hearing and speech. The temporal lobe seems to allow you to understand and comprehend what you hear. The temporal lobe also appears to play a role in putting a name to objects that we see.

The **occipital lobe** is located at the back of your head and it processes the visual input coming from our eyes. Recall we mentioned that the optic nerve was incorrectly named and should be considered part of the brain. The retina actually begins processing visual images and actually throws away over 90% of the information continuously registered by the rods and cones. Layers and layers of neurons in the occipital lobe of the brain continue the process of recognizing visual features that finally allow us to recognize that a piano looks different from a dog.

The **cerebellum** does not officially count as a lobe of your brain, but it has a very important function sitting down low, back there behind your ears. The cerebellum manages the **coordination** of all the muscle movements of your body. When you go to catch a ball, the cerebellum figures out exactly what a dozen muscles need to do, and when, to get that job done. If you decide to write your name, the cerebellum apparently figures out every tiny little movement of your fingers need to make that happen. Awesome does not begin to cover the talents of the cerebellum.

One more part of the brain deserves mentioning. The **brain stem,** tucked below the cerebellum at the top of the spinal cord, seems to have command of all those things your body needs to do that you do not have time to think about. It remembers, without being asked, to keep you breathing, to crank up the right activities in your stomach and intestines to digest your lunch, to get your heart cranked up for the big game, and probably to suggest to your brain that you take off that heavy coat on a hot day.

Now for the Really Important Stuff

What's really going on between your ears? Medical science has struggled with that question for centuries and most would agree we still know very little. Having said that, one can safely bet the coming decades will vastly improve our understanding of how the brain really works. The quest for that understanding has taken scientists in a very different direction than you might expect.

Recall that the brain does its work electrochemically inside cells. The cells in the brain communicate with each other by way of action potentials**.** The cells can generate a pulse of electrical current, known as an **action potential**, that travels down the long "arms" or "legs" that branch out from the cell and eventually touch the surface of other brain cells. We usually think of the cells in our body as being very, very tiny, yet nerve cells have these tiny "arms" that can extend a considerable distance, even many inches. Did I mention that we have many billions of these cells inside our brain? We do. And we have different types of brain cells, and we have some cells in our nervous system that appear to act as **insulators**, just as we use insulators in electrical circuits to make sure signals only go where we want them to go.

Not long after the discovery of the microscope, anatomists recognized that cells in the brain appeared to form layers with a tangle of “arms” (**axons** and **dendrites**) going in all directions between layers. A neuroscientist named Warren McCullock wrote a paper in 1943 with a mathematician Water Pills first suggesting how neurons work together to form **neural networks. Alan Turing**, an important early pioneer in digital computing at the time, became fascinated by these early drawings showing the cellular organization of the brain and recognized that neural networks were indeed “self organizing” computers. He too began to imagine the ways these interactions created logic and allowed humans to learn.

Today computer scientists working with models of neural networks are generating new insight into our understanding of the way our central nervous system has evolved to allow us to shape and understand our environment. It appears that our genetics **differentiates** cells that multiply and interconnect during **fetal** development, but these interconnections grow and adapt throughout our lives. Each neuron in the network decides when to create an action potential in response to the action potentials that other neurons send through their “arms” to its surface. Each brain neuron, over time, can modify the contribution from each input “arm” even to make some inputs have a negative effect they call **inhibition**. The **weighted** combination of action potentials reaching a neuron in the brain determine when that neurons generates its own action potential that it sends to other neurons. The ability of the neuron to gradually change the importance of the various inputs it receives allows the neural network to improve its performance or “**learn**.”

The manner in which the neurons decide how to adjust their sensitivity to inputs scientists call **backpropogation.** Backpropogation has become a sophisticated topic in mathematics and clearly a key to our understanding of how our brain works. In addition backpropogation also has importance in the quest in computer science to create **artificial intelligence** and smart robots. The appreciation of the way the cells in our brain communicate and adjust their communication constitutes the real essence for each of us to begin to understand this incredible organ, much more important than our learning the names of all the anatomical features of the brain.

Brittany Wenger, as a teenager in 2013, created a computer program capable of diagnosing breast cancer from **aspiration biopsy** data better than traditional methods of examination of this data. Brittany used a "neural network" program that taught itself how to detect cancer based on training itself using thousands of examples taken from hospital data libraries. How does this work? Hospital data has specific sets of observations that we might label a, b, c, d…. x, y, z. For each one of these sets of findings for a particular patient we know that they eventually were found either to have a cancer or not. Suppose we think of observations "a through z" as action potentials for individual brain neurons that land on a single neuron we will call neuron Bill in the brain. We want to make Bill into the world's best evaluator of breast cancer. To do that Bill needs to know when a specific set of "a through z" inputs actually indicates cancer. So we are going to guess that Bill should signal cancer if the sum of weighted inputs "a through z" totals more than 100. We need then to find a unique weighting for each input that will make Bill an expert, if it indeed exists.

Brittany started out with a guess for all the weights, but as her computer looked at each case from the hospital data libraries the neural network program adjusted each weight using a backpropogation scheme. The backpropogation scheme essentially looked at each new data sample and asked if a tiny increment in every weight would make Bill's decision better or worse at knowing the right answer. It would then add a tiny step in the apparently best weighting factor to improve Bill's performance. You can think of this as the way you might go about finding the top of a hill you are standing on if blindfolded. You could move your foot around in all directions until you find a direction that appears to move you upward the most and take a step in that direction. Then you would test again and take another step.

Brittany's first effort failed to achieve a solution that worked on new sets of data. She had to **reconfigure** the way she organized the data and start over. Finally she found a weighting that did give the right answer with an amazingly high accuracy.

The human brain has billions of neurons attached to each other in neural networks that are constantly adjusting themselves in a similar manner. The basic construct of the network appears to arise in our **genetic blueprint**, but the weighting of the interconnections, indeed the **density** of the interconnections appears to result from the experience and activities of each brain. When one person spends thousands of hours moving their fingers up and down the neck of a banjo playing bluegrass tunes, they refine neural networks very different from the person who spends a similar amount of time swinging a baseball bat at a curve ball, or practicing a foreign language, or animating a funny cartoon.

That’s what scientists are learning about our brain, and as we learn more, we are going to get better at teaching, and we are going to get better at figuring out how to help our brains work more efficiently and make fewer errors. Google has reported that it has pretty much finished its mission of retrieving information for people, and next it wants to start helping people think in new and powerful ways. Now that’s exciting!

You have probably heard the old adage, “To err is human.” Humans cannot seem to avoid making mistakes. When we explained backpropogation as having a similarity to finding the top of a hill by testing each step, we also illustrated a limitation of neural networks because that backpropogation scheme would take you to the top of the hill you start out on, but not get you to the top of the nearby mountain, because to get there you would need first to go downhill and then back up. The neural networks in our brain have shortcomings we commonly label as fatigue, distraction, overloading, and forgetting. We cannot overcome these with diligence or training or eating the right diet. But as we increasing understand the limitation of our mind, we have the power to develop methods that bridge the gaps to our shortcomings. That is happening all around us even today. Jet fighter pilots do not have fast enough reflexes to fly their planes, so engineers have developed controls that make it possible for the pilot to decide where to go and leave the details to the plane. Similar systems will eventually take over automobile driving and many other tasks in our lives that make us safer and more successful.