THE BRAIN

An introduction to neurology

Second Edition

Written and illustrated by Ellen Johnston McHenry

© 2022, 2014, 2007 by Ellen Johnston McHenry
All rights reserved.

ISBN 978-0-9825377-4-9

Published by Ellen McHenry's Basement Workshop
Pennsylvania, USA
www.ellenjmchenry.com
ejm.basementworkshop@gmail.com

The author gives permission for copies to be made for use with a homeschool or in a single classroom.

PLEASE NOTE:
Although I have done my best to present up-to-date information on the brain, the science of neurology is growing and expanding rapidly. I encourage the reader not to rely on this booklet alone, but to use other sources of information, also.

Nothing in this booklet should be used to diagnose any illness or syndrome.

THE BRAIN

An introduction to neurology

by Ellen Johnston McHenry

NOTE ABOUT CHAPTERS:

The chapters in this book are labeled with decimals: 1, 1.5 (one-and-a-half), 2, 2.5 (two-and-a-half), etc. The second half of each chapter has extra information that is directly related to the theme of the whole chapter, but might be just a little bit too much information for younger students. The teacher or parent can decide whether the student should be required to read the second half. For students reading the entire book, the break between chapter halves provides a natural resting point, so that the chapters don't seem so long.

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 even a little reading about the brain, you probably know more about it than any doctor before the 1800s. 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 still 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 high on the stem caused death. Injuries lower down on the stem caused only paralysis of body parts. From this he learned that the top part of 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 shown here 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. It was thought that the areas of your brain that were large (and therefore where your talents were located) would cause your skull to bulge just a little. Thus, 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 until the mid-1800s. If you were unfortunate enough to have a large bump on your skull right above your ear, you would be classified as a "destructive" person. If you had a bump on the back of your head, it was good news—you'd be more likely to be successful at love and friendship. A bump in front of your ear would make you eat too much. (We must wonder how many people's heads did not match their personalities!) Many of these phrenology words are rarely used today, such as "sublimity" (excellence), "suavity" ("cool factor"), "amativeness" (loving), and "approbativeness" (desire for fame).

Not all scientists believed in phrenology, however, and there was an on-going debate among scientists about whether the brain functioned as a whole or was divided up into areas. Modern science has proven that both sides in the debate were right. 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, based on observation, not on wild guesses.

Photograph by Jack and Beverly Wilgus of daguerreotype originally from their collection, and now in the Warren Anatomical Museum, Center for the History of Medicine, Francis A. Countway Library of Medicine, Harvard Medical School. Enlarged using Waifu2x and retouched by Joe Haythornthwaite. Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=64865123

The most famous brain injury of all time happened to a man named Phineas Gage. He lived in the state of Vermont in the 1800s and worked for a railroad company 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 carefully 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 metal rod into a gunpowder hole at the wrong time. The explosion sent the sharp end of the rod up through his head, entering under his jaw and coming right out the top. To everyone's surprise, he survived the accident and seemed to make a complete recovery. He traveled to South America and became a stagecoach driver. He became very attached to his tamping rod and took it everywhere he went. When he posed for this photograph he insisted on holding the rod.

Even though Phineas had appeared to make a good recovery, those who knew Phineas said that the accident had a profound effect on his personality. They said that "Gage was no longer Gage." He was restless, had trouble making decisions, and was often rude. Before the accident, he had been such a nice young man. The rod had damaged the left side of his brain—the area containing his social skills and his ability to make decisions. Eventually, the injury did begin to affect his health and he began having seizures (sudden bursts of intense electrical activity in the brain). He died of a seizure 11 years after his accident. Years later, his skull and his tamping rod were put into a museum.

Modern brain researchers have the benefit of high-tech scanning devices that allow them to look at the brains of living patients without causing them any harm. These scans are known by their initials, **CT** (computed tomography)**, MRI,** (magnetic resonance imaging), and **PET** (positron emission tomography). The CT scan uses X-rays, the MRI uses magnetism and radio waves, and the PET scan traces the path of 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 on the brain while the patient is awake, which allows them to ask the patient 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!

MRI of brain. top view

https://commons.wikimedia.org/w/index.php?curid=3479321

****

ACTIVITY 1.1 Use the Internet to compare types of scans

Use an Internet 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 NOT 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 playlist has been set up for this book. Go to **www.YouTube.com/TheBasementWorkshop**, click on "Playlists." then find "Brain curriculum." The videos are arranged by chapter, so the first few videos are about these types of brain scans. There are also some videos about Phineas Gage.

ACTIVITY 1.3 More about Phineas Gage

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 everywhere 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. Areas that are less active are blue or purple.

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 ***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 who could not speak after having a stroke. He asked their permission to examine their brains after they died. Enough of the patients agreed, that Broca was able to discover visible damage to cells on the left side of the brain in the area of the temple. He 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 died, his body was sent to a special type of surgeon whose job was to examine bodies to determine why the person died. The surgeon 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 Einstein 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.

Illustration credits:

Broca's Area:

By Polygon data were generated by Database Center for Life Science(DBCLS)[2]. - Polygon data are from BodyParts3D[1], CC BY-SA 2.1 jp, https://commons.wikimedia.org/w/index.php?curid=32508617

Wernicke's Area:

By Polygon data were generated by Database Center for Life Science(DBCLS)[2]. - Polygon data are from BodyParts3D[1], CC BY-SA 2.1 jp, https://commons.wikimedia.org/w/index.php?curid=32533678

ACTIVITY 1.5 Find out more about MRI and PET

Use an Internet search engine to find more information on MRI and PET scans. YouTube or another video service could also be helpful. 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 the key words "Einstein's brain" in any Internet search engine. Also, Wikipedia has article titled "Einstein's Brain."

There is 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 water fountain. It receives 35 liters (about 8 gallons) 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. ("Sugar" includes digested carbohydrate foods such as bread, cereal, rice, potato and pasta.)

The large blood vessels at the bottom of your brain 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.

The brain looks wrinkled and folded, and there is a good reason for this. The surface layer, called the ***cortex***, 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. More wrinkles means more surface area, and more surface area means more space for learning and memory.

Inside the skull, the brain is surrounded by a layer of watery fluid called ***cerebrospinal fluid***, which cushions it and protects it from bumps and bangs. 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.

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 takes place. It is also the part that commands your muscles to move and processes information from your eyes and ears.

The word "cerebrum" is the Latin word for "brain." The word root "cere" comes from a very ancient word: "keres," meaning "horn or head." We find this root is a wide variety of words, such as hornet, unicorn, corn, corner, cornea, triceratops, rhinoceros, and carrot.

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." The cerebellum 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. Also, some types of memory are stored here—your "muscle memories," such as how to ride a bike or tie your shoe. The cerebellum 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. Some reflexes are also found here such as gagging, coughing or vomiting. Yes, these are yucky, but they keep you healthy.

Animals brains have basically the same structures as human brains. Can you identity the brain stem, the cerebellum and the cerebrum in this horse brain? Why do you think the brain stem is coming out the side instead of the bottom? (Think of what a horse's head and neck look like.) How big is the cerebellum compared to the cerebrum? Why might horses need their cerebellum to be larger than their cerebrum?

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

In this diagram, we've drawn and labeled the ***cortex***. In a real brain, there isn't a line between the cortex and the rest of the cerebrum (look at the horse brain). The cortex 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. ("Corpus" is Latin for "body, and "callosum" is Latin for "thick.")

If you look straight down on the brain (top view), you can see that there is a split down the middle. The cerebrum has two almost identical halves which are connected to each other on the inside by the corpus callosum. It is believed that the thicker the corpus callosum is, the better the connection between the two hemispheres. Females tend to have thicker corpus callosums, on average, than males do. You would be able to see the corpus callosum on an MRI or CT scan.

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 the first chapter. A real brain doesn't have any lines on it, of course. 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!

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? Anatomy words are often taken from Greek or Latin so they look strange to us. However, their meanings are usually very simple.

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 real workout! The frontal lobe is responsible for monitoring your behavior and the 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. It also has connections to the parts that receive input from your eyes and ears.

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 a signal to the muscles in your arm and hand, causing them to pick up your chess piece and move it to another square. The motor cortex also controls your legs and feet and any other muscle you can move voluntarily.

SENSORY CORTEX: This thin strip is connected to all parts of your body, but especially the skin. It receives messages about things you feel. Your skin has nerves that can sense hot, cold, pain, and pressure. These sensory feelings go into a middle part of your brain first, before they go to the sensory cortex. This middle part of your brain decides if the feelings are important enough to relay to your sensory cortex. This is why you don't notice minor irritations if you are very busy doing something. The sensory cortex has two sides, each one matching up to one side of the body. You might guess that the left sensory cortex matches up with the left side of your body, but the reverse is true. The left sensory cortex goes to the right side of your body, and you right sensory cortex goes to the left side of your body. 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 parts are. If you close your eyes, you still know what your arms are doing. You can bring your hands together without looking. This is your parietal lobe working. 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; it allows you to see objects in your mind. The parietal lobe is very important in the study of geometry and other mathematical concepts. (Remember, Einstein had a large parietal lobe.) Last, but not least, 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 must turn everything right side up and figure 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, above 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. (Do you remember from chapter one how we first learned what the temporal lobe does?) 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. The frontal lobe decides what to say and sends signals to your temporal lobe and your motor cortex. Your sense of smell and your memory of smells are also located in the temporal lobe. Smell memories are often very strong memories because the temporal lobe is located very close to the inner part of your brain where memories are stored.

****

ACTIVITY 2.1 A crossword puzzle about the brain words you've learned

Clues are from chapters 1 and 2.

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 nerves in the skin.
10) The ___ lobe keeps track of where your arms and legs are.
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.

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

CHAPTER 2.5

MORE ABOUT BASIC BRAIN ANATOMY

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

The second layer is called the ***arachnoid*** layer. This word might remind of 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 medicines 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.)

Here are a few more correct technical words for brain parts: The correct name for a 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." It shows 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. The lips and mouth get a sizeable portion of the cortex. If you drew a person with these proportions, it would look very strange indeed!

****

ACTIVITY 2.4 Measure the length of the sensory cortex

The sensory cortex is very wrinkled. You'll remember that the cortex is wrinkled 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. If you don't have a ruler with centimeters you can use inches instead. Scientists prefer measuring with metric units, as they are based on the number 10 and are therefore easier to use in calculations.

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

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.

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.

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 (the units that proteins are made of). Small molecules such as alcohol (ethanol) can also pass through 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 it causes a mild case of poisoning called "intoxication." In common speech, when someone is intoxicated we call this "being drunk."

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 medicine 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 also weaken the barrier. 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) can 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 must maintain the right 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 photographs 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 more 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 Watch some brain anatomy videos

Use the playlist for this curriculum (**www.YouTube.com/TheBasementWorkshop**, click on "Playlists" then on "Brain Curriculum") to watch a few videos. The videos might contain some brain parts we won't cover until future chapters, but they will also review much of what you've just read.)

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. (TIPS: "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

CHAPTER 3

LEFT BRAIN//RIGHT BRAIN

Have you ever heard someone say that they are “left-brained”? What are they talking about? Does that mean half their brain is missing? In the last chapter we always looked at the brain from the side. Now we are going to look straight down on the brain.

From this top view, the cerebrum looks a bit like a perfectly cracked walnut. It’s wrinkly and it’s got that crack, or fissure, down the center. The two halves of the brain are firmly connected in the middle by the corpus callosum (which means “firm body”). The two halves, or ***hemispheres***, look identical. They have the same lobe sections: frontal, motor, sensory, parietal, occipital and temporal. Oddly enough, however, the left hemisphere controls the right side of the body and the right hemisphere controls the left side of the body. We’ve already seen that the nerves from the eyes cross over and connect to the opposite sides in the back of the brain. This pattern holds true for the rest of the brain. No one is sure why this should be the case. Does it confer some kind of advantage? We don’t know.

Recent brain research has turned up marked differences between the left and right hemispheres of the cerebrum, especially in the frontal and temporal lobes. We’ve already learned that the left temporal lobe contains important speech and language centers, Broca’s area and Wernicke’s area. Very rarely, someone will have their language center on the right side, instead of the left. If a brain surgeon must operate on a temporal lobe and is concerned about not harming the speech center, he can do a pre-operative experiment to find out for sure where the patient’s speech center is located. The patient’s right hemisphere is put to sleep for a few minutes with a mild anesthetic, then the patient is asked to answer some simple questions. If the patient can talk and answer the questions, this means that their speech center is on the left side. If they can’t produce any words, then their speech must be asleep, along with the rest of the right hemisphere.

By Polygon data were generated by Database Center for Life Science(DBCLS)[2]. - Polygon data are from BodyParts3D[1], CC BY-SA 2.1 jp, https://commons.wikimedia.org/w/index.php?curid=32508617

In the frontal lobe, the left side is particularly good at logic, mathematical calculations, sequencing, spelling, and vocabulary, while the right side excels in art, music, and creativity.

By studying people who have had brain damage on either the left or right side (and recently aided by the use of PET scans) researchers have been able to come up with a list of what the left and right sides of the cerebrum do:

LEFT
Uses words to name things
Uses symbols to stand for things
Keeps track of time
Understands sequences
Organizes
Counts and calculates
Uses logic and reasoning
Reads music (sheet music)

RIGHT
Puts pieces of information together
Sees similarities between things
Sees patterns
Sees the "big picture," not details
Appreciates and creates music
Good at drawing, painting and sculpting
Recognizes faces
Uses intuition and has "hunches"

You can see that both sides are important. The brain was designed so that the two sides would work together and complement each other. Most people use both sides of their brain about equally, though they may tend to use one side a little more than the other. When someone says that they are "left-brained," they usually mean that they are better at math and logic than they are at music and art. It might also mean that they get caught up in the details of a project and lose sight of the overall plan. People who are disorganized or have trouble keeping track of time sometimes explain it as being too "right-brained." There isn't always a correlation between hemisphere dominance and handedness. Left-handed people are not always "right-brained." Plenty of artists are right-handed.

People who use one hemisphere almost exclusively are called ***savants***. They are extremely rare, and are of great interest to researchers. Savant syndrome can be caused by injury, but sometimes people are just born that way. The side they use gets extremely good at what it naturally does well. The side they don't use gets behind in its development, leaving the person with disabilities. There is a famous case of a man from Colorado, USA, whose left hemisphere was damaged by an accident in childhood. As he grew up, the right side overcompensated for the loss of the left side and he developed into a sculpting genius. He is so talented that he can sculpt any animal perfectly after seeing it only once. If you look at the "left side" list above, you will be able to guess what he can't do. He can barely talk, and he can't read, write or count. He must rely on other people to help him with basic life skills like cooking, cleaning and making appointments.

ACTIVITY 3.1 Meet Alonzo Clemens and other savants

If you go to **www.YouTube.com/The BasementWorkshop**, you can watch a short video about Alonzo Clemons, the sculpting savant from Colorado. There are also videos about other people with savant syndrome. Remember, "savants" are not just people who are good at what they do. They have genius qualities in one area, but they also have serious deficits. Kim Peek, for example, has almost perfect recall of everything he reads (and he reads a lot!) but is mentally disabled in other ways and will always need someone to take care of him. The most fortunate savanat is Daniel Tammet, who suffered seizures during his early childhood. The seizures left him with autism, but also with amazing abilities to recognize patterns in math and in language. As a young adult, Daniel was able to learn social skills and oversome much of his autism. He can now talk about what it is like inside his head, how he literally sees numbers and simply "reads landscapes" in order to do a calculation.

ACTIVITY 3.2 Fighting for dominance: witness a struggle between the hemispheres!

The two hemispheres usually cooperate by taking turns being in charge. These turns can last a split second, a few minutes, or several hours, depending on what we are doing. Both hemispheres are still active, but one is the boss. In this activity you will actually watch the hemispheres taking turns every few seconds.

Put this page about 2-3 feet (50-80 centimeters) in front of you. Relax your eyes and cross them until you see a third (somewhat blurry) circle in the middle with the blue and red circles right on top of each other. If you stare at this overlapped image, you will see it alternate back and forth from red to blue to red to blue. The white line in the middle will go back and forth from horizontal to vertical, along with the color change. This switching back and forth is your left and right hemispheres taking turns being dominant. When blue is on top, your right side is dominant. When red is on top, the left side is dominant. Remember, the eyes are attached to the opposite sides of the brain.

ACTIVITY 3.3 Use the left side of your brain

Can your left hemisphere figure out what these place names are? (places in the USA)

ACTIVITY 3.4 Use the left side of your brain again

Make an interesting-looking squiggle in each of these boxes:

ACTIVITY 3.5 Use the right side of your brain

Now make an exact copy of each squiggle in each of these boxes. You will be drawing using the right side of your brain. You'll have to look carefully at the originals, above.

ACTIVITY 3.6 Use the right side of your brain again

Three of these figures are identical, even though they are pointing different ways. One of them is reversed left to right, making it different. Which one is different? You will have to use the right side of your brain to rotate them in your mind.

CHAPTER 3.5

MORE ABOUT LEFT BRAIN/RIGHT BRAIN

What would happen if you cut the corpus callosum so that the hemispheres could no longer cooperate? Any volunteers to try it? Of course not. No one would volunteer for such a drastic experiment! Fortunately for brain researchers, there are a few people out there who absolutely had to have their corpus callosum cut in order to save them from a deadly problem with their brain (such as severe epilepsy). After they recovered from the surgery, they allowed researchers to study their rare condition. These patients seemed to be normal. They could walk, talk, read and play sports much the same as they had before their operation. However, if researchers showed a picture of an object, such as a spoon, to the left eye only, the person could not say what it was because the nerves from the left eye travel to the right side of the brain, and the right side does not have language ability. If they showed a picture of a spoon to the right eye only, the person could say, "Spoon," but they could not pick out the spoon when given a selection of objects on a table. This experiment showed that the left side can name objects, but cannot match shapes. The right side can match shapes, but cannot say names. It is the corpus callosum that tells each side what the other side is doing.

This statue was inspired by a painting by Renaissance artist Arcimboldo. The left side of your brain sees fruits and vegetables. The right side sees a face.

In a similar experiment, researchers asked these "split-brain" patients to look at a picture of a face similar to the one shown here. Obviously, one side looks like a woman and the other looks like a man. The patients were asked to focus on that dot you see there on the forehead. While the patients were focusing on that dot, the researchers asked them to say out loud what they were looking at. Since the left hemisphere contains the speech center, the left hemisphere would need to be dominant in order to speak. Therefore, it would focus on the image coming from the right eye (the nerves cross over, remember) and the patient would say out loud, "I see a man." But if they were then shown another page, with two faces on it, a normal male face and a normal female face, and were asked to point to what they saw, they always pointed to the female face. (You can see "split-brain" patients doing these experiments if you go to the YouTube playlist for this curriculum, or use key words "split brain experiments" in another online video service.)

Very few of us have had our corpus callosums cut. Even if we tend to use one side a little more than the other, we still use both sides. However, some of us have one hemisphere that seems to be dominant most of the time. This can make learning a challenge if we are put into an environment that favors the side we don't use as well. Researchers have determined that without intending to do so, most traditional school programs tend to favor the left side. This puts right-side-dominant learners at a disadvantage. For example, right-side-dominant students will often struggle with spelling and seem unable to learn how to spell using traditional methods. Very few educators will figure out why these students aren't doing so well, or will be willing to make changes in the classroom to adapt to right-brain learners. Fortunately, the situation is better now than it used to be, as more teachers are learning about hemisphere dominance, and are trying to find ways to make their classrooms more "right-hemisphere-friendly."

ACTIVITY 3.7 Do you have a dominant hemisphere?

Put a check mark on the side that is more true. If they are both equally true, or if neither of them is true, put a check in the middle. Try to put as few checks in the middle as possible. (NOTE: This activity could be difficult for younger students. You may not have enough life experience to have figured yourself out.)

___ I would rather do a report than a project.	____	I would rather do a project than a report. ___
___ When I listen to someone talk, I don't see any images in my mind, I just hear words.	____	When I listen to someone talk, I often think of visual images of what they are saying.___
___ When I read, I love to remember lots of the details because they are important to me.	____	When I read , I just like to get the main idea and not worry too much about the details. ___
___ When I talk, I don't usually use hand gestures, I just talk.	____	When I talk, I often use my hands and arms to illustrate what I am saying. ___
___ On tests, I prefer multiple choice or true/false questions, not essay questions.	____	On tests, I prefer essay questions, not multiple choice or true/false.___
___ It really bugs me if things are out of place in my room.	____	My room is seldom really clean, but it just doesn't bother me. ___
___ I do my best thinking while sitting up.	____	I do my best thinking while lying down. ___
___ I like the arrangement of furniture in my room to stay the same, if possible.	____	I like to rearrange my room often. ___
___When learning a dance step, it is easier for me to learn the sequence of moves first, talking my way through them.	____	When I learn a new dance step, I just like to imitate the teacher. ___
___ I can tell how much time has passed, even without looking at a clock.	____	I can easily lose track of time. ___
___ When I get answers to math problems, I can explain how I got the answer.	____	I can get the answer to a math problem, but I cannot explain how I got it. ___
___ I like to have fun without taking risks.	____	It's fun to take risks. ___
___ I don't mind following someone else's plans if they are explained well.	____	I don't like following plans. I like to make my own plans. ___
___ I can figure out what will happen next.	____	I can "sense" what will happen next. ___
___I spread my work out evenly over the given time I have to do it.	____	I don't mind waiting until the last minute to get my work done. __
___ I like to read the instruction manual before I try to put something together.	____	Instruction manuals just confuse me. I do better without them. ___

To score this test, you simply add up the number of checks on the left and the number of checks on the right. Whichever is greater is the hemisphere that is more likely to be dominant.

CHAPTER 4

DEEP INSIDE THE BRAIN

We've talked about the basic anatomy of the brain and haven't even mentioned functions such as memory and emotions. Obviously, there must be more parts to the brain. In this chapter, we will take a look at the parts that lie deep within the center of the brain.

The center of the brain is a confusing place. There are all sorts of blobs in weird shapes. It's even more complicated than this picture. We've tried to simplify it as much as possible without leaving out any major parts. There are also connecting tissues, empty spaces, and a few other small parts that have difficult Latin names and serve mainly as helpers for these main parts.

NOTE: This drawing shows the left side of the inner brain. To see some 3D picture of brain anaomty, go to www.neuroanatomy.ca and click on "3D' then on "3D neuroanatomy models." The pictures spin around so you can see all sides.

Once again we see the cerebellum and the parts of the cerebrum: frontal, motor, sensory, parietal, occipital and temporal. The left temporal lobe is sort of peeking out from behind the cerebrum. The right temporal lobe, the one that would have been in front, had to be removed in order to see the middle of the brain.

We've already learned about the corpus callosum. It's the "firm body" that joins the two halves of the cerebrum, and lets each half know what the other half is doing. Lurking above (and sort of on the outside of) the corpus callosum is the ***cingulate gyrus*** (SING-gew-late JIE-rus). It is actually part of the cerebrum, but it is attached to the ***limbic system*** (the inner parts that we'll learn about on the next page). It may help relay information from the inner parts of the brain out to the cerebrum, as well as helping to control your emotional responses.

The brain stem has been divided into three pieces: the ***medulla oblongata***, the ***pons***, and the ***mid-brain***. The ***medulla oblongata*** controls automatic funcctions like breathing, blood pressure, and the beating of the heart. Your medulla keeps these systems running even when you are asleep. The actions of sneezing, coughing (the kind you can't control) and vomiting are also in the medulla. Some cough medicines (the suppressants) act on the medulla, dulling it a bit, giving you some relief from the urge to cough.

The ***pons*** controls your waking and sleeping cycles. Even if you don't set an alarm clock, you will still eventually wake up, thanks to your pons. It also acts as a connector between the cerebellum and the cerebrum and so may help with balance and posture.

The ***mid-brain*** is sort of a "crossroads" for nerve pathways. It helps direct in-coming signals and routes them to the correct area of the cerebrum. It seems to help in the processing of information coming in from the eyes, ears and muscles. It also seems to have a function in swallowing and salivation reflexes, as well as helping to regulate sleep cycles and body temperature.

Now we will look at just the very center of the brain. This area is sometimes called the "lower brain" because it is below the cerebrum. Some of these parts work together to form the ***limbic system*** (hippocampus, fornix, amygdala) which controls emotions and is also connected to memory. If you search the Internet for diagrams of the limbic system or the lower brain, you will find that no diagram exactly matches any other. Few of them will agree on the shapes and sizes of the parts, and they will even use different labels than the ones we will show here. Brain parts are not as distinct and easy to identify as bones or digestive organs. The brain is a mass of soft, squishy, lumpy gray stuff, and, for the most part, the divisions between parts are not easy to see. Scientists can disagree on where the divisions are or whether some parts are just sub-sections of other parts. And just to confuse you further, they can't agree on names. (For example, the pituitary gland can also be called the hypophysis.) This makes learning lower brain anatomy very difficult. We've tried to make it as simple as possible, but please be aware that the diagram you see here might not match the diagrams in other textbooks. (In fact, it doesn't even match our own drawing on the previous page!)

Going counterclockwise:

CORPUS STRIATUM: We already know that "corpus" means "body." The word "striatum" means "striped." This area has a mildly striped texture if you cut it open. The corpus striatum is connected to many other parts, though in diagrams you can't see these connections. The striatum seems to be involved in decision making, especially when it relates to movement. It also seems to play a role in motivation and in response to rewards and punishments. It is here that "conditioned" responses develop. The famous example of this is "Pavlov's dogs," where Mr. Pavlov conditioned his dogs to salivate every time they heard a bell ring because they had learned that when the bell rang they would soon be fed. Their corpus striatums connected the sound of a bell to food, and sent signals to the nerves in glands in the mouth to produce saliva. The corpus striatum is also one of the parts that controls addictions; it can make inappropriate connections to behaviors and rewards, causing the addicted person to choose patterns of behavior that are actually harmful to them.

BASAL GANGLIA: "Basal" means "at or near the bottom," and "ganglia" is the plural form of "ganglion" which means "tangle, knot, or clump." So the basal ganglia are little "knots" of nerve fibers that sit at the bottom of the cerebrum. These might be the strangest parts on the diagram. Their job is to stop, or inhibit, movement. They are constantly putting the brakes on your motor cortex. The reason that you can think about moving your arm or leg without actually doing it is thanks to your basal ganglia. If the basal ganglia become less active and stops sending out inhibitory chemicals to the thalamus, this will cause a person to make unnecessary motions that they cannot control (as in Tourette's syndrome). If the basal ganglia are too active, (as seems to be the case with Parkinson's Disease), the thalamus will be suppressed and won't relay signals to the motor cortex.

OLFACTORY BULB Although it might sound like a light bulb factory, it is really the nerve that brings in smelling sensations from the nose. Your nose hooks up to your brain very close to the place where memories are stored, the hippocampus. Some scientists think this is why you almost never forget a smell. The odor sensations are then sent to the temporal lobe where your brain determines what kind of smell it is.

HYPOTHALAMUS: The word "hypo" means "under," so the hypothalamus is located under the thalamus. Although this part is very small, it has lots of important jobs. It keeps your body temperature and your blood pressure constant, makes you feel hungry or thirsty, helps sort out emotions coming from the amygdala, manufactures chemicals that control growth, and sends chemical messages down to the pituitary gland telling it when to release its chemicals. The hypothalamus is quite a multi-tasker! Think of the hypothalamus as your body's balance regulator, letting other organs know when there is too much or too little of something. The scientific word for keeping the levels of things constant is ***homeostasis.***

PITUITARY GLAND The pituitary *(pit-TU-it-tary)* gland produces chemicals that make you grow. It also makes hormones that causes a child to mature into an adult.

AMYGDALA: The amygdala *(ah-MIG-dahl-ah)* is found at the end of the center for emotion, especially strong emotions such as fear and anger. It turns on the bodily functions that are related to these emotions, like increased heart rate and sweating. This emotional center just happens to be at the tip of the part that controls memory, which is possibly why our strongest memories are things we felt strongly about when we experienced them.

HIPPOCAMPUS: This is the Latin word for seahorse. The photograph below shows a hippocampus (with fornix attached) next to a seahorse. Pretty amazing, eh? Probably what we now call the fornix (the tail of the seahorse) was originally considered to be part of the hippocampus. The hippocampus lets you compare new experiences to old ones that you already have in your memory, and it also puts memories into longterm storage. It's sort of like a librarian, finding a place to put new books (memories) and pulling out old ones (remembering) when you need them.

hippocampus librarian

By Hippocampus_and_seahorse.JPG: Professor Laszlo Seressde-rivative work: Anthonyhcole (talk) - Hippocampus_and_seahorse.JPG, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9451294

MAMMILLARY BODY: This tiny part is still somewhat of a mystery. What we know about it comes from cases of brain damage. It seems to play a part in memory, and might also help us remember places and travel routes.

PINEAL GLAND: This gland, not surprisingly, is shaped like a pine cone. The pineal gland produces a hormone called ***melatonin***, which helps to control sleeping and waking cycles. It is connected to special light-sensing cells at the back of the eye. All mammals have this gland and in some mammals it also controls seasonal cycles, such as hibernation. Recently, it has been discovered that the pineal gland also stimulates production of new bone.

THALAMUS: This part helps to sort out all the sensory signals coming from in from the body and then either ignore them or send them on to the appropriate lobes of the cerebrum. The thalamus also seems to be the center of ***consciousness***. Damage to the thalamus can cause a person to go into a coma (a prolonged period of unconsciousness deeper than ordinary sleep). The **ANTERIOR THALAMUS** is the front part of the thalamus. It is sometimes classified as part of the limbic system, along with the hypothalamus. It receives input from the mammillary bodies via the fornix. It is connected to episodic memory (more about this in a later chapter).

FORNIX: "Fornix" is Latin for "arch." This part connects the hippocampus to other brain parts.

VENTRICLES: These are not labeled—they are the "empty spaces" between all the parts, and are filled with cerebrospinal fluid. If you read the next section, you will learn more about them.

ACTIVITY 4.1 “The Brain Song”

Here is a silly song about some of the parts of the brain. You can download the audio tracks at this web address: www.ellenjmchenry.com/Brain

THE BRAIN SONG

I woke up Monday morning, just like I always do;
Without my PONS to get me up, I’d sleep the whole day through.
My faithful old MEDULLA had worked all through the night,
To keep my heart and lungs working right.
Oh, my brain stem works so hard,
It does so many things I disregard (oh, how very boring)
Thinking about my CEREBELLUM is a snore,
Without it, though, my head would hit the floor.

I jumped up out of bed, then, and dressed without a fuss;
I was getting signals from my HYPOTHALAMUS.
I went out to the kitchen for cereal and a bowl,
But what a sight for my OCCIPITAL!
Pans and dishes filled the sink.
My TEMPORAL LOBE could smell the garbage stink (oh, how very awful)
Thinking about the chores that waited for me there
Was more than my poor FRONTAL LOBE could bear!

I fled that great disaster using MOTOR CORTEX nerves,
I hurdled over forks and crumbs and Friday night’s hors d’oeuvres.
My FRONTAL LOBE decided to take me out the door,
But I really wish I’d seen that apple core!
As I gazed up at the ceiling,
My TEMPORAL LOBE could “hear the birdies sing” (oh, how very lovely)
Thinking I’d made my poor PARIETAL go lame,
My LIMBIC SYSTEM felt a sense of shame.

Oh, my HIPPOCAMPUS would make sure
The memory of this day would long endure (oh, how very poignant)
Thinking I’d better get some help with my hygiene,
I dialed 1-800-42-GET-IT-CLEAN!

ACTIVITY 4.2 A crossword puzzle about brain parts

ACROSS:

3) This lobe control your muscles
7) This “vaulted arch” connects the hippocampus to other brain parts.
8) This lobe keeps track of 3D space and where all your body parts are in that space
11) This lobe interprets sensory signals from your eyes
13) This part lets you know when you need food
14) This pea-sized part controls your growth
16) This brain area is in the middle and seems to “direct traffic” sorting out incoming signals
17) This lobe receives input from your ears and and nose, and also contains your speech center
18) This lobe receives signals from your sensory nerves

DOWN:

1) This C-shaped part is on the bottom of the cerebrum and connects it to the inner brain.
2) This tiny part controls strong emotions such as anger and fear.
4) The name of this lobe means “little brain.” It helps with balance and coordination.
5) This is the bottom of the brain stem and controls breathing and the beating of your heart
6) This nerve “bulb” receives input from the nose.
7) This lobe is where your rational thinking occurs, such as decision making and calculations.
9) This is the part that puts memories into long term storage, and is also able to retrieve them. It is like your librarian.
10) This part of the brain stem wakes you up in the morning.
12) These are empty spaces filled with fluid.
15) This part is above the hypothalamus and seems

ACTIVITY 4.3 Color-coded brain parts again

This activity is just like the one you did on page 10, except that we have added the parts deep inside the brain. Decide on a color code and make the parts of the brain match their boxes in the key. (If you run out of colors, use patterns like dots or stripes.) This diagram is not identical to either diagram in this chapter, but that's okay because brain diagrams are rarely the same. You can figure it out!

- ☐ cerebellum
- ☐ sensory cortex
- ☐ cingulate gyrus
- ☐ hippocampus
- ☐ amygdala
- ☐ mid-brain
- ☐ temporal lobe
- ☐ occipital lobe
- ☐ motor cortex
- ☐ corpus callosum
- ☐ thalamus
- ☐ pituitary
- ☐ pons
- ☐ basal ganglia
- ☐ parietal lobe
- ☐ frontal lobe
- ☐ fornix
- ☐ hypothalamus
- ☐ olfactory bulb
- ☐ medulla oblongata
- ☐ pineal gland
- ☐ mamillary body

CHAPTER 4.5

MORE ABOUT DEEP INSIDE THE BRAIN

A feature that is found deep inside the brain and is easy to overlook is... empty space! Since empty spaces are not really brain parts, it is easy to forget about them when you are studying the brain. Yet they deserve to be mentioned because they are vitally important.

The empty spaces in the brain are called ***ventricles***. The shape of the ventricles was first discovered by pouring wax into a cow's brain. The wax filled up the ventricles, then cooled into a solid. The brain tissue was removed, leaving just the ventricle-shaped blobs of wax.

Human brains have four ventricles. Their shape is difficult to describe and just as difficult to draw. However, here is an attempt to show you what they look like (with their shapes simplified a bit). The ventricles are filled with the same fluid found between the brain and the skull: ***cerebrospinal fluid***, or ***CSF***. This fluid is produced by cells in the ventricles and consists of water, sugar (glucose), proteins, vitamins, and minerals. You may remember from a previous chapter that the brain produces about a spoonful of fluid every hour.

The fourth ventricle flows down into the spinal cord. The fluid drains down through the center of the spinal cord, and then out the bottom to be reabsorbed and recycled by other body tissues. If, for some reason, the fluid cannot drain properly, the result can be that the ventricles become over-filled with fluid and start to expand, putting pressure on the brain. To correct this problem, surgeons can install a plastic drainage tube (called ***shunt***) that allows the extra fluid to drain down into the stomach.

Spaces inside the brain are filled with either brain cells or cerebrospinal fluid, never air or blood. If someone has surgery to remove part of their brain, that empty space will fill up with cerebrospinal fluid. If the brain begins to shrink, due to disease or aging, the brain fills that space with fluid. Doctors can look at MRI scans of the ventricles to help them diagnose diseases such as schizophrenia or Alzheimer's. If they see large ventricles, that means the brain has gotten smaller.

We do not know for sure why there are ventricles deep inside the brain, but here are some good guesses. First, they help provide protection for the interior parts. Second, they sort of "float" the brain so it doesn't press down so heavily on the top of your spine and neck. (If you have ever picked someone up while in a swimming pool, you know that objects seem far less heavy when they are floating in water.) Third, the extra fluid may be necessary to nourish the inner brain parts that do such important jobs, such as regulating your body temperature and your appetite. The fluid delivers nutrients to the brain cells and removes wastes. Your brain needs those ventricles!

ACTIVITY 4.5 Color two more PET scans

Color these PET scans using the number code. You will be able to compare the scans and see how Alzheimer's can cause loss of brain tissue, thus creating larger ventricles.

1 = yellow or light green 2 = blue 3 = purple V = leave blank (ventricle)

Normal patient

Patient with Alzheimer's

ACTIVITY 4.6 More about ventricles

To get a better idea of what the ventricles look like, you need to see them from different angles and with brain parts in and around them. You can use Google or some other image search engine and the key words "brain ventricles" to look at a variety of ventricle illustrations. You will notice how different they look in each illustration.

You may turn up one of Vesalius' illustrations from the 1500s, such as the one shown here. (Remember Vesalius from way back in chapter 1?) In case you are wondering, he probably did not actually see a real head cut this way. He liked to be creative with his drawings and thought it would be humorous to make this one look like a living head.

There are also some videos abut ventricles posted on the YouTube channel (**www.YouTube.com/TheBasementWorkshop**. Ventricles may seem an unlikely topic for someone to make a video, but actually there are quite a few good videos to choose from. Several of the videos use accurate 3D models of these spaces, so you see how they are connected and how they relate to the brain lobes around them. Happy ventricle viewing!

CHAPTER 5

BRAIN CELLS

The basic building blocks of your body are ***cells***. There are different kinds of cells, designed to do particular jobs. For example, the cells in your skin were designed to cover and protect you, the cells in your muscles were designed to contract, the cells in the back of your eyes were designed to sense light, the cells that line your sinuses were designed to produce mucus, and red blood cells were designed to carry oxygen. The size and shape of the cell depends on its job.

What do brain cells need to do? They must be able to generate chemical and electrical signals. The electrical signals in your brain cells are not like the electrical current found in the wires of your house. Some cells found in other animals—electric eels, for example—are able to generate large electrical currents, but fortunately your brain cells can't do this.

There are actually two types of cells in the brain: ***neurons*** and ***glial*** *(GLEE-ul)* cells. Neurons get all the attention because they have the exciting job of producing the electrical signals. However, there are ten times more glial cells in the brain than there are neurons, so they must be very important. We aren't going to forget those glial cells and will come back to them in a minute, but first, let's look at neurons.

If your forearm was a neuron, the fingers would be dendrites.

Neurons are strange-looking cells. They have a large area, called the ***cell body*** with lots of little branches coming out of it. These little branches are called ***dendrites***, which is Greek for "tree branches." If you made a neuron model with your hand, your fingers would be the dendrites.

The long skinny part is called the ***axon***. The end of the axon branches off, but they are not called dendrites, they are just the ends of the axon. Notice that at the ends of the axon are little knobs (the ***terminal knobs***). We'll find out what they do on the next page.

The neuron's electrical signal goes only one way. It starts in the cell body, travels down the axon, and stops at the ends of the axon. It never goes the other way. The branching dendrites are like antennae, or receivers, that "listen" for signals from other cells. The knobs at the ends of the axon are like transmitters that send the signal out to other cells.

This neuron is actually the type that is found outside of the brain, the kind that makes the nerves found throughout the rest of your body. Brain neurons don't have those marshmallow-looking things around their axons. More about this on the next page.

Inside the main body of the cell are little parts called ***organelles***. The organelles you find inside a neuron are the same organelles you find in all the other cells of the body. The nucleus is the place where the DNA (deoxyribonucleic acid) is located. The DNA provides all the instructions for the cell so it knows how to do its job. The mitochondria's job is to produce energy for the cell. Many of the other small parts are like little factories or warehouse that make, store, and ship complex molecules that the cell needs.

The pads along the axon—looking like a string of sausages or marshmallows—make the ***myelin sheath***. ("Sheath" just means "cover.") They act like the rubber insulation around electrical wires that keeps the electricity inside the wires. Myelin *(MY-ell-in)* is made mostly of fat, with a little protein mixed in, and is a very good insulator. The myelin allows the electrical signals to travel at speeds up to 270 miles per hour (435 km/hr). Each "sausage" (or marshmallow) is actually a living cell, albeit an extremely weird cell that is flatter than a pancake and is all rolled up. These cells are called ***Schwann cells*** (after Mr. Schwann, who discovered them). Schwann cells are found around nerves in the body. In the brain, the myelin sheaths are produced by a special kind of helper cell you'll meet in chapter 4.5.

The little knobs at the ends of the axons have a special job. They must relay the electrical signal to the next neuron down the line. However, it's not a simple task, because neurons don't actually touch each other. There is a microscopic gap between them, called the ***synapse*** *(SIN-aps)*. The electrical signal cannot jump across this gap. The knobs must make chemicals that act as little ferry boats, crossing the gap. When these little ferry boats reach the far shore (the dendrites of the next neuron) they deliver their message: "Hey, cell! Start an electrical signal immediately!" These chemicals are called ***neurotransmitters***. After they cross the gap, they must be recycled. The neurotransmitters might be dissolved or they might be gathered up and put back into the terminal knobs. This process happens very quickly so that you can make the same motion repeatedly.

Scwann cells are blue. Yellow is axon. The pink thing is the Schwann cell's nucleus. Look how many time the Schwann cell is wrapped around the axon!

As you read the following paragraph, you might want to put your finger on the first neuron (on the left) and move your finger along with the described actions.

The first neuron starts an electrical signal. It travels down the axon until it reaches the knobs. The knobs make chemicals that go across the gap. The chemicals deliver their message to the next neuron and it begins to fire off an electrical signal. The electricity travels down that axon until it reaches the knobs, then stops. The knobs make chemicals that cross the gap and deliver the message to the next neuron. The next neuron fires off an electrical signal. The electricity travels down the axon until it reaches the knobs. The knobs make chemicals. And it continues on this way, alternating between electricity and chemicals, until the signal finally reaches its destination, wherever that is. The destination might be a muscle cell, in which case the electrical signal would cause the muscle cell to contract. Some signals stay inside the brain. (In which case, we wouldn't see Schwann cells.)

Now, what about that other kind of cell, the one everyone tends to forget about? Those poor unsung heroes are the ***glial cells***. The word *glial (GLEE-ul)* is related to the word "glue." Glial cells act a bit like glue in the brain, holding all the neurons in place. You don't want those delicate axons and synapses getting bumped out of place! For every one neuron there are at least ten glial cells, possibly as many as fifty.

Glial cells are the caretakers of neurons. They feed them, clean up after them, protect them, and repair them if they get damaged. All the neurons need to do is send their signals. The neurons in this diagram are yellow.

There are several kinds of glial cells. The green cells in this diagram are called ***astrocytes.*** ("Astro" means "star.") This diagram only shows a few astrocytes, just to keep the picture simple. In reality, many astrocytes surround the neurons. Astrocytes protect the synapses so they don't get bumped out of place. The process of learning requires pathways to be formed from neuron to neuron, and these paths included a route through specific synapses, so they must stay lined up. You can see how the astrocyte "hugs" a blood vessel (the red tube). The astrocyte absorbs oxygen and food from the blood, then passes it along to the neurons.

The blue cells are called ***oligodendrocytes*** and are the equivalent of Schwann cells because they form rolled covers around axons. The round part of these cells is the cell body. One cell body has a few ("oligo" means "few") dendrites going out from it, and the end of each dendrites forms a sheath that will wraps around an axon.

The dark red cells are ***microglia*** and are the infection fighters inside the brain. The pink cells at the top produce cerebrospinal fluid and are therefore found lining the walls of the ventricles.

By Artwork by Holly Fischer - http://open.umich.edu/education/med/resources/second-look-series/materials - CNS Slide 4, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=24367125

Here is another diagram showing the same thing. In this drawing, the artist has not shown us the astrocyte touching a blood vessel, but we do see the astrocytes connecting with the dendrites of the ***ependymal*** cells (eh-PEND-i-mal). Touching the astrocytes allows the ependymal cells to communicate with the other brain cells. This is import when neurons or other glial cells become damaged. In 1999, it was discovered that an ependymal cell can change to become one of the other cells types. This is very helpful when the brain is trying to recover from a stroke, one of the brain injuries we mentioned in chapter 1. In a stroke, one of the brain's tiny blood vessels becomes blocked and the brain cells die due to lack of oxygen.

By OpenStax - https://cnx.org/contents/FPtK1zmh@8.25:fEI3C8Ot@10/Preface, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=30147916

Now let's go back to talking about neurons for a minute. We know the basic structure of all neurons: they have dendrites, cell bodies, and axons. The exact shape of neurons can vary quite a bit, however, depending on their location and their job. They can have long dendrites and short axons, or short dendrites and long axons. They can be almost symmetric (balanced) or they can look lopsided.

Can you spot the axon in all of these neurons? (There's no answer key, so don't worry if you guess wrong.) In several of them, the dendrites are very long and the axon is the only short one. Can you find a neuron with a very long axon that splits in two at the end? The extremely bushy one is found in the cerebellum and is called a ***Purkinje cell*** (*pur-KIN-gee),* named after the discoverer.

A FAMOUS BRAIN SCIENTIST

Santiago Ramón y Cajal *(Ra-mone ee ka-HALL)* was a Spanish neuroscientist who lived from 1852 to 1934. As a child, Cajal was trouble-maker. At age eleven he actually went to jail for a short time because he destroyed a neighbor's garden gate with a home-made cannon. Though he did not do well in school, he was an excellent gymnast and learned to draw and paint quite well. Even though his father was an anatomy teacher at a medical school, he doubted that his son would ever have an academic career so he apprenticed him to a shoemaker.

However, one summer, young Santiago went with his father to a graveyard to pick up bones that could be studied by his father's anatomy students. Santiago was allowed to make sketches of the bones, and these drawings were so good that it was obvious to everyone that he should be allowed to try going to medical school. He did well, and after serving as an army doctor for a few years, he became a professor at several major universities.

Cajal became an expert at examining tissues under a microscope and was especially interested in looking at brain tissue. He learned about a staining technique that would stain only neurons and leave the background blank. This was just what he needed to study the patterns made by neurons. He discovered the synapse, and suggested that connection between cells' dendrites was mechanical process necessary for learning. In 1906 he was awarded the Nobel Prize in Medicine.

Here are some of Cajal's most famous drawings:

Cells from the cerebellum of a chicken.

Purkinje cells from a human brain.

Purkinje cells from a pigeon brain.

Cells from a human sensory cortex.

Cells from the optic lobe of a bird brain.

Cells from a rat hippocampus.

ACTIVITY 5.1 Neuron videos

Don't forget to check out the neuron videos on the Brain playlist.

ACTIVITY 5.2 Vocabulary and riddles

Read each clue and write the correct word, with one letter on each line. After you are finished, used the numbers under the lines to write the correct letters to form the answer to the silly riddles.

1) The type of cell that sends electrical signals: ___ ___ ___ ___ ___ ___
9

2) This part of a brain cell contains the nucleus and organelles: ___ ___ ___ ___ ___ ___ ___ ___
6

3) This type of cell wraps around the axons of nerve cells found outside the brain: ___ ___ ___ ___ ___ ___ ___
17 21

4) These branch off the cell body of a neuron. ___ ___ ___ ___ ___ ___ ___ ___ ___
18

5) This fatty substance is what provides the insulation around axons: ___ ___ ___ ___ ___ ___
1

6) These cells are the infection-fighting cells of the brain: ___ ___ ___ ___ ___ ___ ___ ___ ___
16

7) This type of cell attaches to both capillaries and neurons: ___ ___ ___ ___ ___ ___ ___ ___ ___
3

8) This type of cell insulates brain axons: ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
15 7

9) This is a very small blood vessel: ___ ___ ___ ___ ___ ___ ___ ___ ___
11 12

10) The type of brain cells that outnumbers neurons 10 to 1: ___ ___ ___ ___ ___
13

11) This type of cell is found only in the cerebellum: ___ ___ ___ ___ ___ ___ ___ ___
14

12) This type of cell make cerebrospinal fluid: ___ ___ ___ ___ ___ ___ ___ ___ ___
2

13) The chemicals cross the synapse: ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
4 10

14) This is the tiny gap between neurons: ___ ___ ___ ___ ___ ___ ___
19

15) This is where the DNA (instructions) are found in a cell: ___ ___ ___ ___ ___ ___ ___
5

16) The Greek word "dendrite" means: ___ ___ ___ ___ ___ ___
8

17) This part of a neuron is very long and skinny, and wrapped by insulation: ___ ___ ___ ___
20

RIDDLE #1 What has a head, but no brain? ____ ____ ____ ____ ____ ____ ____
1 2 3 4 5 6 7

RIDDLE #2 What happened to the man who had his left hemisphere removed?

____ ____ ‘ ____ ____ ____ ____ ____ ____

ACTIVITY 5.3 Color these brain cells

You've seen several images of brain tissue. Now it's your turn to choose the colors. Put the color into the square, then color the appropriate areas on the diagram. Cerebrospinal fluid can be white if you want to do less coloring. Also, draw some cell parts inside that neuron's cell body. (Make it look like the other cell bodies.)

- ☐ astrocytes
- ☐ oligodendrocytes
- ☐ neurons
- ☐ cerebrospinal fluid
- ☐ microglia
- ☐ ependymal cells
- ☐ capillary
- ☐ red blood cell

ACTIVITY 5.4 Optional: Draw some brain cell cartoons

Science doesn't always have to be serious. Here is a cartoon called "Glial Cell Appreciation Day" (for those heroes who do all the work of keeping neurons alive and well).

If you like to draw cartoons, you can use the space below to make your own silly brain cells. Brain and nerve cells have such strange shapes that you don't have to worry about making them look "right." Any way you draw them will be just fine! (Your cartoons do not need to look like these.)

CHAPTER 5.5

MORE ABOUT NEURONS: HOW THEY MAKE ELECTRICAL SIGNALS

The electrical signal made by a neuron isn't like the electricity that flows through the wires of your house. The neuron's source of positive and negative electrical charges is atoms of sodium and potassium. These atoms come from the food and drink that you take in. Both sodium and potassium are very common atoms and most types of food have plenty of both. The atoms end up all through your body, but some will find themselves near a neuron.

If you could put a tiny electrode into a neuron and measure the electrical charges both inside and outside the cell, you would find that the inside of the cell had a more negative charge than the outside. This difference is called the ***potential*** because it's this difference that gives the neuron its *potential* to work. This is the normal or "resting" state of neurons: the "***resting potential***." Strange as it may seem, unbalanced (more negative inside than outside) is "normal" for a neuron.

Both sodium and potassium atoms have a positive electrical charge (+), which makes them ***ions***. An ion is any atom, or piece of atom, that has an imbalance of electrons and protons and therefore carries a positive or negative charge. If the atom has more protons it will have a positive charge. If it has more electrons, it will have a negative charge. The membrane of the axon contains tiny pumps that have the ability to pump ions in and out of the cell. It pumps three sodium ions out for every two potassium ions it lets in. Two in, three out. Two in, three out. You can see that the more it pumps, the more positive the outside becomes, compared to the inside. (There would be other types of ions floating around, too, but we are only showing the sodium and potassium to keep things simple. Na stands for sodium because years ago it was called "**na**trium." Potassium used to be called "**k**alium.")

The outer membrane of the axon has tiny "gates" all along it. They are usually closed to sodium, keeping sodium on the outside (1). When a nerve impulse comes along, the number of ions outside the gates becomes so great that the gates burst open (2), allowing sodium ions to come flooding in, until there are equal numbers of sodium ions inside and outside the cell. The gates snap back to their closed position (3), and then the cell has to begin pumping all over again (4). Two K's in, three Na's out. Two K's in, three Na's out. Eventually it manages to get things back to "normal" with more (+) charges outside than inside.

The gates are either open or closed—they can't be partially open. It's an "all-or-none" situation. The signal strength that is required to open the gates is called the ***threshold***. If the signal is below the threshold strength, the gates will remain closed. As soon as the signal hits threshold strength, the first gates snap open. Even if the signal is much stronger than threshold level, the result is the same: the first gates snap open.

This opening and closing of gates starts at the dendrites, then moves into the axon. Section by section, the gates open and close all the way down the axon. As soon as the gates slam shut, that section of the axon immediately begins resetting itself by pumping two in, three out, two in, three out. (And all of this happens in less than 1/1000 of a second!) This continuous action of gates opening and closing down the axon is called the ***action potential.***

The opening and shutting of the gates down the axon is almost like a weird sort of domino rally, with each domino being a section of the axon. But unlike the dominoes, which take a lot of work to reset, the neuron does all the work of resetting automatically, with its sodium-potassium pumps.

Now we are going to add an extra twist to the story of how the signal goes down the axon. To make the journey even faster for the electrical signal, it takes "short cuts." Wherever there is a section of myelin padding, (those marshmallow or sausage looking things), the signal can sort of skip right over that section and jump right to the next one. The tiny gaps between the Schwann cells (or oligodendrocytes in the brain) are called the ***nodes of Ranvier***. (Guess who discovered them... yep, Mr. Ranvier.)

Videos of this can be very helpful. There are some videos posted on the Brain Curriculum playlist on the YouTube channel.

So the signal skips along from node to node, without having to go the complete distance in between. To go back to our domino analogy, it would be like having an extra long spacing bar representing the myelin sheath area. The signal is strong enough to push the bar, which immediately sets off the next section, without having a bunch of dominoes in between.

Dominoes seem to fall very quickly, so we might not think this extra speed is very important. But to the neuron, it makes a big difference. Signals such as reflexes can't be just fast, they have to be lightning fast. Your reflexes need to do things like pull your hand back from the stove in a split second.

Now we need to look at what happens to the nerve impulse when it reaches the synapse. As we've already learned, when the electrical signal reaches the end of the axon, it comes to a screeching halt. It cannot cross the gap. The electrical signal must be translated into a chemical signal that can cross the synapse.

The ends of the axons look like little knobs. They are called the ***pre-synaptic knobs***, since they are they come before (pre) the synapse. The electrical signal allows calcium ions to flow into the cell, causing little bubbles (***vesicles***) full of chemicals to "fuse" with (sort of melt into) the outside wall of the knob, thus spilling their contents into the gap. There could be tens of thousands of vesicles in each synaptic knob.

These neurotransmitter chemicals go across the synapse and touch the membrane of the dendrite on the other side. There are special places on the dendrite's membrane called ***receptor sites*** where these chemicals will stick. When they stick, they cause the dendrite to open its sodium-potassium gates, which begins an electrical nerve impulse in that neuron. As soon as the chemicals have done their job, they are either dissolved or are recycled back into the terminal knob.

Understanding how synapses work allows you to understand how some drugs work. Poisons called ***neurotoxins*** can prevent the neurotransmitters from sticking to the sites they are supposed to stick to. For example, a poison called *curare* (kyur-ar-ay) made from the skin of a South American frog, does an even better job of sticking to these receptor sites than the neurotransmitter chemicals do. The curare gets in there and sticks to all the sites

so that there are none left for the neurotransmitters. This prevents the electrical signals from passing from neuron to neuron. No signals are sent to the heart telling it to beat. No signals are sent to the lungs telling them to breathe. You die quickly. There are also neurotoxins that do the opposite. They flood the gap so the signals won't stop. Opposite problem, but just as bad.

On the other hand, some chemicals can be a great help to the synapses. A medicine called diazepam can cause the chemicals to do a better job of sticking to the receptor sites, thus improving the functioning of the synapse. You could think of them as little dock workers, standing at the docking sites, helping the chemical ferry boats to get docked more quickly and safely. This medicine is used to treat anxiety and muscle spasms.

Another problem that can occur with the synapses is that the neurons do not seem to make enough neurotransmitter chemicals. Medicines called SRIs (serotonin re-uptake inhibitors) stop the body from dissolving the neurotransmitters so fast after they are used. (Serotonin is one of the neurotransmitters.) The SRI chemical slows down the rate of dissolving so that there are more neurotransmitters in the gap.

Why must the electrical signal be converted into a chemical signal, then back to an electrical signal between every cell? It seems that this allows the nervous system to be more responsive and more flexible. The nervous system is incredibly sophisticated and capable of fine-tuning itself to respond to the smallest changes. The synapse and the neurotransmitters somehow contribute to this sensitivity and adaptability. Some neurotransmitters even inhibit (try to stop) an electrical signal from getting passed along. This adds another layer of complexity.

ACTIVITY 5.5 REVIEW: What are these things?

See if you can remember what these things are. If you can't remember, try using the process of elimination. Do all the ones you are pretty sure of first, and save the harder ones for last. The possible answers are listed below.

1) _____
2) _____
3) _____
4) _____
5) _____
6) _____
7) _____
8) _____
9) _____
10) _____
11) _____
12) _____
13) _____
14) _____
15) _____
16) _____
17) _____
18) _____
19) _____
20) _____
21) _____
22) _____
23) _____
24) _____
25) _____
30) _____
31) _____
32) _____
33) _____
34) _____
35) _____

WORD BANK (possible answers): dendrites, pons, motor cortex, frontal lobe, gyrus, glial cell, ventricles, vesicles, node of Ranvier, arachnoid layer, dura mater, pia mater, cingulate gyrus, occipital lobe, nucleus, sulcus, dura mater, sensory cortex, corpus callosum, arachnoid layer, cerebellum, receptor site, olfactory bulb, Schwann cell, parietal lobe, thalamus, medulla oblongata, midbrain, fissure, homunculus, neurotransmitters, skull, cortex, PET scan, synapse, MRI scan, axon knob

ACTIVITY 5.6 "Odd one out"

One of the words in each group doesn't belong with the others because it doesn't fit into the same category that the others so. Your job is to try to figure out what that category is (what most of the words have in common) and why that last word does not fit. For example, in this group of words: (heart, brain, bones, shoes) the word "shoes" doesn't fit because it is not a part of the body. In this group: (eyes, nose, stomach, ears) the word "stomach" doesn't fit for two reasons. It is not located on the head, and it is not part of your senses.

The first word groups are easier, and it gets a bit harder as you approach 10. Feel free to look back at the text to get clues!

1) limbic, temporal, frontal, occipital
2) fissure, gyrus, sulcus, synapse
3) PET, CAT, MRI, CRV
4) oligodendrocyte, astrocyte, microglia, neuron
5) oxygen, carbon dioxide, water, sugar
6) Schwann, Gage, Wernicke, Ranvier
7) fornix, hippocampus, mammillary bodies, medulla oblongata
8) frontal lobe, temporal lobe, olfactory bulb, occipital lobe, sensory cortex
9) temporal lobes, pituitary gland, ventricles, parietal lobes, olfactory bulbs
10) knob, synapse, dendrite, axon, nucleus
11) threshold, homeostasis, saltatory conduction, action potential
12) potassium. curare, serotonin, diazepam,

ACTIVITY 5.7 TRUE or FALSE challenge

Are these statements true or false? Write T or F in the blanks.

1) _____ Wernicke's area is in the frontal lobe.
2) _____ Cerebrospinal fluid is made by special cells that line the ventricles.
3) _____ "Dendrite" is the Greek word for "tree branch."
4) _____ Schwann cells are not found in the brain, only in the body.
5) _____ When a neuron is at resting potential, it is more positive outside and more negative inside.
6) _____ A "shunt" is a tube that drains extra blood away from the brain.
7) _____ The hippocampus is necessary for storing memories.
8) _____ The BBB (Blood Brain Barrier) keeps alcohol molecules out of the brain.
9) _____ The amount of wrinkles a brain has is a better clue about intelligence than size is.
10) _____ The thalamus is sort of like a relay center in the brain, sorting and routing signals.
11) _____ Most capillaries in the body are "leaky" but not the capillaries in the brain.
12) _____ Cerebrospinal fluid carries neurotransmitters to the synapses.
13) _____ Astrocytes keep neurons from shifting around and losing contact with each other.
14) _____ There are two ventricles, one in each hemisphere.
15) _____ The hypothalamus is in charge of hunger, thirst, and body temperature.

CHAPTER 6

NETWORKS OF NEURONS

Neurons join together to form long, complicated networks. These networks could be compared to our systems of telephone wires, or electrical wires, criss-crossing the landscape, connecting all of our houses and businesses.

Imagine that we've gone back in time, when houses all had physical telephone wires going into them. (Many houses do still have a "land line.") Each telephone can represent a neuron. Let's have an exciting piece of news represent a nerve impulse. We'll let letters represent the telephone callers.

Person A calls person B, who calls person C, who calls person D, who calls person B (oops, sorry person B — you've already been called), who calls person E, who calls person F, and so on and so forth, until everyone knows the news.

The news could have taken a different path, with the same result. Person A could have called person C, who called D, who called B, who called F, who called E, who called G, who called H.

What if person E was the first to know? E calls D and person D makes two calls, to both C and G, and these two then call the rest.

As you can see, there are many possibilities for how the message could travel. The same is true in your nervous system, but on a grand scale: there are BILLIONS of different paths that a nerve impulse can take.

The path that a nerve impulse takes is called a ***neuronal network*** (or ***neural network,*** though the primary meaning of this term now seems to be digital networks using computers). There can be many networks within the same group of neurons. Each pathway is considered a separate network. A network involves thousands of neurons.

Each time your brain processes information of any kind, an electrical impulse traces out a pathway through the brain. The diagrams above show the same network of neurons (the lines would be dendrites and axons), but with five different pathways traced out. If exactly the same process is repeated, the nerve impulse will travel that route again. The more the pathway is traveled, the easier it becomes for the impulse to travel it. It's a little bit like walking through a field of tall grass. The first time, there is no path to follow and you have to work at getting through. You may have to beat down the grass with your feet, and walking seems difficult. The next time you walk through, it's a little bit easier because you can still see the bent grass where you went through before. By the tenth time you go over that path, the grass is permanently crushed down and a trail is starting to appear. By the 100th time you go across, the path has become easy to travel.

For example, the first time a baby tries to move his hands, the nerve impulse has no path to follow—it must find its own way across the brain. The second time the baby tries to move his hands, the nerve impulse can try to follow the pathway it first made. If successful, the nerve impulses will keep going the same route again and again, until the pathway is so easy to follow that the baby no longer has to concentrate on trying to move his hands—the motion becomes automatic.

The first time you try to play a song on the piano, it is very difficult. You have to think about every note and every movement of every finger. The nerve impulses are creating brand new pathways across the brain. As you play the song again and again, the nerve impulse retraces that path again and again. The pathway becomes more like a roadway. Soon, the impulses are zipping along effortlessly. You can play the song with very little effort.

Once a pattern of basic networks has been created, the brain can add more to them. For instance, once you know how to play simple songs on the piano, you are ready to start working on harder ones. Your brain will build on those first networks and add the new information about the harder songs. As the networks get more and more complex, you will be able to tackle more difficult songs. You can't play the difficult songs if you have not built the basic networks first, using the simple songs. .

These network pathways can stay in place for a very long time, sometimes for your whole life. Many people find that skills they learned when they were young stay with them right through old age. Of course, if you only took piano lessons for a couple of months, don't expect your pathways to be as permanent as those of someone who took lessons for years. The pathways do need to be reinforced in order for them to become permanent. (In other words, practice makes perfect!)

Here is a diagram that shows a network becoming more complicated:

The networks we have drawn so far are just cartoons, not real ones. Real networks look very messy. You can't tell what's connected to what. This is more what a real network of neurons looks like:

The above image really is a photograph of neurons. The images below aren't photos of neurons, but the art is based on the idea of neuronal networks.

ACTIVITY 6.1 Neuron network math

Even in just a single neuron there are different pathways that an impulse could take. It could go in and out any of the dendrites and axon knobs. Let's consider a small, very simple neuron with only three dendrites, A. B, and C, and three axon knobs, 1, 2, and 3. How many possible pathways would there be?

We could make a list of the possibilities. Use your finger to trace out each possibility as you read it.

In at A, out at 1	In at B, out at 1	In at C, out at 1
In at A, out at 2	In at B, out at 2	In at C, out at 2
In at A, out at 3	In at B, out at 3	In at C, out at 3

That's a total of 9 pathways.

How about a neuron that is just a little bit larger? Let's look at one with 5 ways in and 5 ways out. Trace the possibilities with your finger as you read them.

In at A, out at 1	In at B, out at 1
In at A, out at 2	In at B, out at 2
In at A, out at 3	In at B, out at 3
In at A, out at 4	In at B, out at 4
In at A, out at 5	In at B, out at 5
In at C, out at 1	In at D, out at 1
In at C, out at 2	In at D, out at 2
In at C, out at 3	In at D, out at 3
In at C, out at 4	In at D, out at 4
In at C, out at 5	In at D, out at 5
In at E, out at 1	In at E, out at 4
In at E, out at 2	In at E, out at 5
In at E, out at 3	

That's a total of 25 pathways in just one neuron!

Do you notice a pattern?
3 ways in, 3 ways out, is 9 pathways;
5 ways in, 5 ways out, is 25 pathways.
What would 6 ways in and 6 ways out give you? 6 x 6 = 36 pathways.
What about 6 ways in and 7 ways out? 6 x 7 = 42 pathways.

Real neurons in the brain can have dozens of dendrites branching out. What if you found a cell with 25 dendrites and 10 axon knobs? That would be 250 pathways in just one neuron!

Now, what if we form a very small network made of just two simple neurons? Let's consider these two beautiful specimens. You are going to fill in the pathway possibilities this time. We'll get you started, though.

In at A, out at 1, then in at D, out at 4
In at A, out at 1, then in at D, out at 5
In at A, out at 1, then in at D, out at 6

In at A, out at 2, then in at E, out at 4
In at A, out at 2, then in at E, out at 5
In at A, out at 2, then in at E, out at 6

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
I In at ___, out at ___, then in at ___, out at ___

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
I In at ___, out at ___, then in at ___, out at ___

In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___
In at ___, out at ___, then in at ___, out at ___

That's a total of 27 pathways, right? 3 x 3 = 9, and 9 x 3 = 27. [3 x 3 x 3 = 27] The third (x 3) came from the additional ways out: 4, 5, and 6.

What if the axon knobs could go to any of the next dendrites? What if 1 could go to either D, E, or F, and 2 and 3 could each go to D, E, or F? How many possibilities would that make? Making a list for that one will take up too much space. Let's find a short cut. We know that one neuron with 3 ways in and 3 ways out will provide 9 pathways. So we have 9 pathways for the top neuron, and 9 for the bottom neuron. If we match up each of the top pathways with each of the bottom paths, we will get 9 x 9 = 81 pathways.

Would you like to calculate the possible pathways for the network shown here on the right? No? Okay, we'll let you off the hook as long as you ponder the following piece of information: Your brain contains about 100 billion neurons (100,000,000,000). The number of neuron networks possible in your brain is billions of billions—a number so high that you probably don't even know a name for it. Just think of how much potential you have—make the most of it!

ACTIVITY 6.2 Reinforce some of your neuronal networks

We learned in this chapter that the more you reinforce the neuronal networks in your brain, the longer they will last. You've been creating new networks in your brain as you have been learning about the brain. Let's go back over some of the information you have learned and see if those networks are still in place.

Can you remember the six basic lobes of the cerebrum?

1) _____ 2) _____

3) _____ 4) _____

5) _____ 6) _____

Label the drawing with the numbers of the lobes.
Label the brain stem as number 7 and the cerebellum as number 8.

7) What is the brain stem in charge of? _____

8) What does the cerebellum do? _____

9) The hippocampus was named after this animal: _____

10) What brain part acts like brakes, inhibiting (slowing down or stopping) motions? _____

Use your memory of "The Brain Song" to fill in these blanks:

11) *"Without my _____ to get me up, I'd sleep the whole day through."*

12) *"Oh, what a sight for my _____."*

13) *"Pans and dishes filled the sink. My _____ lobe could smell the garbage stink."*

14) *"I fled that great disaster using _____ _____ nerves."*

15) *"My _____ lobe decided to take me out the door."*

16) *"My _____ lobe could hear the birdies sing."*

17) The part of your brain that makes you feel hungry and thirsty is the _____.

18) The olfactory bulb connects the brain to the _____.

19) One of the pituitary's jobs is to make you g_____.

20) The neuron's "branches" are called the _____.

If the statement applies to the left hemisphere, put an "L" in the blank.

If the statement applies to the right hemisphere, put an "R" in the blank.

21) Very good at logic and mathematical reasoning: ____

22) Creative and musical: ____

23) Sees the "whole picture" better than the details: ____

24) Good at drawing and sculpting: ____

25) Uses words to name things: ____

CHAPTER 6.5

MORE ABOUT NEURONAL NETWORKS

Nerve impulses trace out particular pathways, making unique networks in the brain. These networks store information as simple as knowing that sandpaper feels rough, to more complex facts such as 8x7= 56. Networks are formed when our bodies learn to do certain tasks, such as riding a bicycle or typing on a keyboard. Even our limbic system forms networks of emotional patterns. We have networks for things like social customs and what kind of clothes we find fashionable. Neuronal networks are the way our brains work.

What would happen if a brain formed networks based on faulty information? What if you learned your multiplication tables all wrong? How long would it take for your brain to cancel those old networks and build new ones for the right answers? Or what if you grew up in a neighborhood full of mean dogs. How many good experiences with dogs would it take to convince you that most dogs are friendly? Erasing old networks is often more difficult than building new ones. Networks die hard, and re-routing nerve impulses is hard work.

Have you ever moved to a new house? If so, you know that for the first few weeks or months in your new house, you have to think about where to find things. If you want to find your tennis racket, for example, the first thing that pops into your mind is where the tennis racket was stored in your old house. Then your frontal lobe has to say, "No, that's not right any more. We need to form a new network for the location of the tennis racket." Then you think about where you put the racket when you moved into your new house. The act of thinking about it forms a new network. If you chose a storage place in the new house that is very similar to the storage place in the old house, such hanging on the wall in the garage, this can make it easier to form a new network, because you can use part of the old network. Your old network knew that tennis rackets hang on walls in garages. If this is still true, then you can use that part of the old network and just replace your mental image of the old garage with the new one.

What happens when huge neuronal networks are not needed any more? Do they disappear right away? No, and in fact, they probably don't ever get erased entirely. If you move to a different country and learn a new language, you won't forget your native language. Those networks will stay there unless you were very young and the networks were not firmly in place yet. If you stop practicing the piano, over the years your brain will lose some of those connections, but you will probably never forget basic scales and simple songs. On a sad note, if you lose a friend or family member, your neuronal networks that allowed you to have a relationship with that person don't go away. The networks are still there, and not being able to use them any more will make your limbic system generate feelings of sadness and loss.

The phase of life when the greatest number of networks are formed is childhood. We make networks during our whole life, but not to the extent that we do when we are young. Children's brains develop networks more quickly, making as many as 1000 connections per minute. For example, the best time to learn a second language is between age 2 and age 12. It's not impossible after that, but it is much more difficult. (Strangely enough, most American schools don't offer foreign language to students under the age of 12. Hopefully, that will change in the future.)

Now, don't confuse making new networks with making new neurons. In general, you don't grow new neurons. (Recent research has found that neurons can regenerate more than we thought they did, especially in a few particular areas of the brain, but the general principle still holds.) Even children don't grow new neurons. By the time a baby is born, it has pretty much all the neurons it will ever have (over 100 billion of them!). It's the connections between those neurons that increase and grow throughout life.

A well-known brain researcher named Marian Diamond (at UC Berkeley) did experiments with rat brains to show how networks develop and grow. She wanted to see how much effect an animal's (or human's) environment has on the structure of its networks. Dr. Diamond designed an experiment where she raised groups of rats in different environments, then looked at their brains to see what happened to the neurons. She had four groups of rats. The rats in the first group were all by themselves and had no toys. The second group were all by themselves, but had toys. The third group had other rats in with them, but no toys. The fourth group had both toys and other rats with them. After the rats died, she opened up their brains and looked at the neurons under the microscope. What she found looked something like this:

Group 1
Rats all alone, no toys

Group 2
Rats alone but with toys

Group 3
Rats with friends, but no toys

Group 4
Rats with both friends and toys

NOTE: These are not Dr. Diamond's actual slides. They are facsimiles (fak-SIM-al-ees) designed to illustrate the general idea of what she found. She counted the number of dendrites in certain areas.

Dr. Diamond concluded that environments affect the complexity of neuronal networks. She found that the rats in group 4 were just plain smarter. They learned mazes more easily and could adjust to changes in their environment with less stress. Other researches who have done similar experiments have found that the number of glial cells increases, as does the number and the width of capillaries (those tiny blood vessels that bring the oxygen and food to the cells). The number of energy-producing mitochondria inside the neurons can also increase.

Another special feature of neural networks is something called ***plasticity***. You can see the word "plastic" in there. Plastic is a substance that will do a lot of bending before it will break. Some plastics are pretty soft and can be reshaped if they are heated a bit. Plasticity in the brain means the ability to change and adapt when necessary. Networks can often be rebuilt if they are damaged. In fact, the brain is really good at re-routing nerve signal "traffic" around damaged areas. New networks will form to replace old ones. For example, when someone has a stroke, part of their brain does not receive enough oxygen and some of the cells die. Those cells were in networks. What happens then? The signals can't travel their usual paths. The brain sends out signals to move a hand or to say a word, and nothing happens. Fortunately, over time, and with a lot of therapy, new networks can form (Perhaps, we learned in the previous chapter, some ependymal cells will migrate to the damaged area and turn into glial cells or neurons.). Stroke patients often recover to an amazing degree, and their lost abilities will gradually return. Even older brains still have an amazing amount of plasticity.

The most dramatic example of plasticity is when a child has to have an entire hemisphere surgically removed in order to stop the progression of a disease. This type of operation is called a ***hemispherectomy***. ("Ectomy" means "removing a part.") Can you live with only half a brain? The first surgeon to attempt this daring procedure was probably pretty nervous! However, his patient would certainly have died without the operation, so he went ahead. Amazingly, the answer is yes. Children can adapt and survive quite well with only one hemisphere. The remaining hemisphere gets busy and starts growing billions of new connections. It isn't long before the child is walking and talking again. This works for children, but what about adults? Adults have a lot of plasticity in their brains, but not as much as children do. Adults would not make such a good recovery after this type of operation. Probably they would have permanent paralysis on one side of their body (the side that had been controlled by the hemisphere that was removed). For this reason, surgeons won't perform this operation on adults.

What if the reverse happens—if a body part is removed but the brain parts it was wired to remain intact? Those brain parts are now "out of a job," so to speak. What do they do now? The same as anyone else—find new jobs! The neurons will try to rewire to other nearby networks. In the sensory cortex this can cause interesting results. A soldier who had lost an arm reported to his doctors that every time he shaved his face he had the sensation that his missing arm was tingling. The face and arm areas in the sensory cortex are close together, so it is likely that the arm neurons were sneaking over to the face area and "borrowing" incoming sense signals.

How does rewiring actually occur? This is a hot topic in brain research right now. One big discovery was that those Schwann cells aren't dummies. If an axon is severed, the Schwann cells form a tube through which the axon can regenerate itself. The Schwann cells somehow know in which direction the tubes should go, so the neurons can reconnect with other neurons. This process is a bit slow, though. Nerve damage can take months, or even years, to heal. But your body will try. Unfortunately, the body is often not able to overcome major trauma to the nerves in the spinal cord. Researchers are working hard to find a way to help spinal cord nerves reconnect.

* * * *

ACTIVITY 6.4 Decipher the punch lines

Use the clues to write the words in the boxes. Then use the numbers under the boxes to fill in the letters that will give you the punch line to the jokes.

The space between two Schwann cells is a: [ ][ ][ ][ ] [ ][ ] [ ][ ][ ][ ][ ][ ][ ]
19 16 6 10

In the brain, these cells make myelin sheaths: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]
13 12 3

These cells make tunnels for injured axons: [ ][ ][ ][ ][ ][ ][ ]
1 22

Chemicals that cross synapses are: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]
9 20 5 17 18

The ends of the axon look like: [ ][ ][ ][ ][ ]
4

The insulating substance along axons: [ ][ ][ ][ ][ ][ ]
7 2 23 21

The places where neurotransmitters stick:
(on the post-synaptic membranes, pg 26.4) [ ][ ][ ][ ][ ][ ][ ][ ] [ ][ ][ ][ ][ ]
15 14 8 11

What did the Hollywood movie producer say to the little neuron who auditioned for a part in his movie?

[ ][ ][ ] , [ ][ ][ ] , [ ][ ][ ] ' [ ][ ] [ ][ ][ ] [ ][ ][ ][ ][ ][ ][ ][ ][ ]
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

The ability of the brain to rewire after injury: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]
9 8 1 11

The brain has over 100 _____ neurons: [ ][ ][ ][ ][ ][ ][ ]
4

A type of neurotransmitter (starts with S): [ ][ ][ ][ ][ ][ ][ ][ ][ ]
3 7 13 10

A group of neurons that function together: [ ][ ][ ][ ][ ][ ][ ]
5 12 14 15

The brain structure that stores memories: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]
2 6

What is the brain's favorite television channel?

[ ][ ][ ] [ ][ ][ ][ ][ ][ ] [ ][ ][ ][ ][ ][ ][ ]
1 2 3 4 5 6 7 8 9 10 3 11 12 13 14 15

CHAPTER 7

LEARNING AND MEMORY

When our brain forms a new network between neurons, we call this ***learning***. You probably think of learning as just memorizing spelling words or math facts. A neuroscientist would say that every experience your brain records is learning, even if it is something simple like the feel of snowflakes falling on your hand, or the sound of someone's voice. Our brains are constantly learning, and most of this learning does not take place in a classroom. Every little piece of information that our brain takes in creates a unique pathway through the brain.

Now we are ready for the next step: networks of networks! All the individual networks are parts of larger networks that we call ***memories***. A memory is a group of networks that work together. Each one of the individual networks can be in a different part of the brain, yet they function together to form a single memory.

Let's use a specific memory as an example: your most recent visit to your favorite restaurant. The network for the shapes and colors of the walls and furniture went from your eyes to the outer part of your occipital lobe. The delicious smells went from your nose into your temporal lobe. The voice of your friends and family went from your ears through a network that ended up in the cortex of one or both temporal lobes (but in a different area from the smells). The meanings of the words your heard were stored in yet another area of the cortex, not the same one that the sounds went to. Your feelings as you entered the restaurant formed a network in the area that stores emotions. In order to remember this experience, all of those individual networks have to work together to bring back the complete memory. The visual network, the smell network, the sound network, the meaning network, and the emotional network all have to fire at the same time to recreate that memory.

This is very similar to how a computer works. It stores information in various parts of the disk or drive. To bring a certain text back onto the screen, it must find all those pieces of information and bring them back together again. When the computer starts running out of large storage space, it must start stuffing tiny bits of information in any "crack" it can find. This slows it down. We say the information is becoming "fragmented" and it's time to "defrag" your computer.

The part of your brain that stores memories is the very outer layer of the cerebrum, called the cortex, or the "***gray matter.***" (You remember that from chapter 2, right?) The very outer layer of the cortex is called the ***neocortex***. Your neocortex is like the available disk space on your computer. However, unlike your computer, you will never run out of space. Brains have an amazing capacity to store information.

An MRI showing gray and white matter.

The gray matter is gray because it is made of the cell bodies of neurons. The cell bodies are darker in color than the axons. In a living brain, the gray matter is more of a pinkish-tan color because of all the blood. The gray matter doesn't appear truly gray until the brain is disconnected from its blood supply and preserved in chemicals. The white matter is white because it is made of axons that are covered with myelin, which is very light in color. There is no myelin in the gray matter.

Neuroscientists are not sure exactly what happens in the neurons to make a memory permanent. Some say it is a chemical change in the body of the cell. Others say it is a change in the dendrites. One of the most recent theories suggests that there are important changes to the internal protein"skeleton" that allows cells to maintain their shape. To make it even more mysterious, there are people who have died on the operating table, and then been revived, who have come back with memories of hearing and seeing things taking place in the room while their brains were registering zero brain activity! If someone tells you that scientists have figured out exactly how memory works, don't believe them. There are many things about memory that we don't yet understand.

However, even though we don't completely understand how memory works, we do know some basics. Let's take a look at these basics.

`We can classify memories into these categories: ***sensory, short-term, and long-term*.**

Every memory starts out as a ***sensory memory,*** and only last a few seconds. Your senses are constantly being bombarded by sight, sound, smell and touch sensations. Your brain can keep track of up to 12 of these for just a few seconds. It then sends them through a screening system that determines which ones are important and which are not. This screening system isn't something you think about, it's automatic. Only the sensory information that is really important, or that "catches your attention," is sent on to the short-term memory.

Your ***short-term memory*** lasts a bit longer than the sensory, but it still lasts for only a minute, at most. The short-term memory is sort of like a scratch pad or clip board, where temporary notes are posted. This scratch pad, located in the very front of your frontal lobe, can only hold about seven items (absolute maximum of nine), no matter how intelligent you are or how good you think you are at remembering things. (Even Einstein's short-term memory was the same as yours.) When the capacity of seven items is reached, your brain must erase the first ones to add more. If you want to keep any of the items longer than one minute, your brain must transfer them to ***long-term memory***.

One of the brain parts responsible for transferring short-term memory to long-term memory is the ***hippocampus***. The "sea horse" librarian is responsible for taking short-term memories from the prefrontal cortex behind your forehead and transferring them to your permanent memory storage in the outer layer of your cortex, the ***neocortex***. The hippocampus acts as a librarian sorting out incoming books. It classifies each piece of short-term information as sight, sound, smell, taste, touch, meaning, or emotion, and sends the pieces on to the appropriate storage area in the neocortex. It can reverse this process, too, and bring the bits back together to recreate the memory. Then, when you have finished remembering, it puts everything back.

You may have noticed that the hippocampus is right near the ***amygdala***. The amygdala is in charge of strong emotions. This placement is not accidental. The close association between these brain parts causes you to remember things better if there is strong emotion attached to them. This is why you remember so clearly conversations you had when you were angry, or what the weather was like on a day that something terrible happened to you, or what you were wearing when you embarrassed yourself in front of your friends. Have you ever found that answers to questions that you get wrong, stick in your head better than the ones you get right? Strange as it might seem, that fear of failure actually helps you remember better. And that embarrassing moment with your friends—your hippocampus will make sure that you never forget <u>not</u> to do that again!

One special part of long-term memory is stored not in the cerebrum but in the cerebellum. The cerebellum also has an outer cortex that can store information. Since the cerebellum is in charge of coordinating body movement, it is in the cerebellum that you remember how to ride a bike, do a dance, or play notes on a musical instrument.

We know this partly because of a modern-day Phineas Gage—a man whose extremely improbable injury has let brain researchers discover some of the secrets of how the brain works. Clive Wearing lives in England. He used to be a well-known musician and symphony conductor. One day, in 1985, he came down with a virus. Usually this virus only causes cold symptoms or small sores in and around the mouth. For some unknown reason, the virus traveled up to his brain (got past the blood-brain-barrier) and began attacking his hippocampus. In a matter of days, he began losing his ability to transfer short-term memories to long-term storage. Within a few weeks he was reduced to having a seven-second memory. After a few years, he improved slightly and now he has about a 30-second memory.

Can you imagine what that would be like? Every thirty seconds your brain would totally "reset" and you would have no memory of anything that happened even one minute ago. If someone left the room and came back a minute later, it would be as though they were just coming in for the first time. If you tried to watch a television program, you wouldn't be able to remember anything that happened before the commercial break. If you tried to cook, you'd forget the recipe halfway through. Life would be impossible!

Brain researchers have been studying Clive, and have done MRIs to see what parts of his brain were damaged. The most amazing thing they have discovered is that he has retained his memory of how to play music. He can sit at the piano and play very difficult pieces that he had memorized before his accident. He can also play cards, tie his shoes and ride a bicycle. This tells us that the parts of memory involved in bodily actions do not need to go through the hippocampus. Clive, with no hippocampus, can still play the piano just like he always did. The cerebellum can remember **procedures**, such as how to play Solitaire, or how to put your fingers on the piano keys to play a song. This type of memory is called ***procedural*** memory.

To conclude our story of Clive, don't feel too bad for him. He lives in a very nice house specially designed to take care of brain injury patients. The staff is trained to deal with his special needs and they take good care of him. His wife comes to visit him and he always greets her with hugs and kisses and says how much he loves her. She still loves him, too. (You can "meet" Clive through a video posted on The Brain's youtube channel.)

ACTIVITY 7.1 Meet people with world-class memories

The playlist has some short interviews with world-class memory champions. They all use the Roman "loci" method of memorization (in activity 7.3). The first video shows a man named Andi Bell memorizing (in less than an hour) the location of every card in 10 decks. All of these champions say they started out with normal memories or even poor memories. They'll all tell you they are ordinary people who just decided to improve their memories.

ACTIVITY 7.2 Watch a slide show on "The Anatomy of Memory"

This online slide show is presented by the Exploratorium, a hands-on science museum in San Francisco, CA. This presentation shows dissection of a sheep brain. It is not gross at all. They just show you clean-looking slices of white and gray, and a picture of the inside, showing the corpus callosum, brain stem, thalamus, etc. No blood, no gore, just neat and tidy white and gray parts. And remember, it is a slide show with only still pictures. If you want a video version, they have one, but the picture quality is not nearly as good as the slide show.

http://www.exploratorium.edu/memory/braindissection/index.html

ACTIVITY 7.3 Mnemonics *(Nem-ON-iks)*

Tricks that help your brain convert short-term memory to long-term are called mnemonics (the first "m" is silent, so you say "nemonics"). A mnemonic helps the brain by associating a new piece of information with something already in long-term storage.

The ancient Romans were the first people known to have discovered mnemonics and make use of them. Roman politicians or philosophers would often give very long lectures or speeches and apparently worried that they would forget what they wanted to say. So they devised a system they called "loci," meaning location. The Roman orator would imagine a place he knew well and see each thing he was to remember as a part of that location. For example, if the first three locations he saw in his mind were a couch, a table, and a doorway, and the first three objects he had to remember were a horse, a sword, and a soldier, he might imagine the horse lying on the couch, the sword thrust through the center of the table, and the soldier standing in the doorway.

Mnemonics can also be used to help us spell difficult words. Making up a rhyme or a funny comment about a word that using some of the letters in the word can help us to remember the all the letters. For example, "There's A RAT in sepARATe" can help you to remember that it's spelled with an "a" in the middle, not an "e." Some people use a little sing-song rhyme to help them remember how to spell the state of Mississippi: "M-ISS-ISS-IPP-I" If you have trouble remembering how to spell the word "friends" you might make up something like this: "With school friends, FRIday ENDS the week."

Now it's your turn! Choose three words that you have trouble remembering how to spell. (If you don't have any, then think of a word that a friend or sibling has trouble with.) Make a mnemonic for each of them. Write the spelling word on the line and the mnemonic in the space to the right. (The mnemonics can be silly as long as they work!)

1) _____ Mnemonic:

2) _____ Mnemonic:

3) _____ Mnemonic:

ACTIVITY 7.4 Write about your earliest memory

Can you remember anything from when you were four years old? How about three? If you can remember something from when you were two, you are truly remarkable. If you say you can remember something from when you were one, we won't believe you because at that age your hippocampus was not developed enough to put things in long-term storage. Babies cannot form long-term memories. If someone ever tells you they remember being born, don't believe them. It's scientifically impossible!

What is your earliest memory? Use the space below to tell about it.

CHAPTER 7.5

MORE ABOUT LEARNING AND MEMORY

There are two types of long-term memory. They are known by several names, none of them easy to remember. Don't worry if your brain has trouble putting the names into long-term storage. Understanding what they are is more important than remembering the names.

The first type of long-term memory is called ***implicit*** *(im-PLISS-it)*. It is also known as the ***procedural memory***, which might be an easier word to remember because it relates to learning "procedures" for doing things like tying shoelaces, riding a bike, brushing your teeth, catching a ball, or playing chords on a guitar. These things require your muscles to make a coordinated pattern of movement. Since coordination is the key, this type of memory is centered in your cerebellum. Looks like the man to the right has some incredible implicit memories! Learning how to do a balancing act is a type of remembering, but not something you can put into words.

The second type of long-term memory is called ***explicit*** *(ex-PLISS-it)*. This is what you normally think of as memory. To further confuse you, however, brain scientists have broken down explicit memories into two sub-categories: ***episodic*** and ***semantic***. Actually, their names make them sound more confusing than they really are. Episodic memory is about an <u>episode</u> in your life, like what you did on vacation last year, or the time your aunt embarrassed you at the family reunion. Semantic memory contains facts that you know but don't remember ever learning. You know that a pencil is used for writing, but you don't remember a specific event where you learned that fact. Math facts might even be semantic. You probably don't remember when you learned that 2+2= 4. You just know it.

In the last chapter we learned that short-term memory can hold only about seven items, with the absolute maximum being nine. Even the smartest people in the world can't hold more than nine things in their short-term memory. How, then, do some people manage to remember long lists, making it appear that their short-term memory can hold far more than nine items? The answer is that the brain does something called ***chunking***. Like the name suggests, chunking has to do with chunks. The short-term memory can hold about seven "chunks" of information. However, those chunks can be anything that the brain considers to be one piece of information. For example, if someone read off this list of numbers, and asked you to repeat them, would you be able to do it? 111, 222, 333, 444, 555, 666, 777, 888, 999 That's a total of 27 numbers. Of course, if would be very easy for you to repeat them, because your brain sees this series of number as about only three pieces of information. The first piece of information is that you start to count; the second piece of information is that you say the number three times, and the third piece of information is that you stop when you get to 9. If you were given a similar string, but the numbers went up to 20, it would still be the same three pieces of information, except that you would stop at 20 instead of 9. Counting is something you don't need to use your short-term memory for. Those counting facts are already in long-term storage. It would not matter how high the list went, it would still be just three pieces of information.

How many chunks of information would you need in order to remember this phone number? 222-1492 You might need only two. The first chunk would be "222," and the second chunk is a famous number: the year that Columbus "sailed the ocean blue." What about this phone number? 531-8642 You need to remember to start with five, then count down by odd numbers, then start with 8 and count down by even numbers. That's well under the seven-chunk limit. When remembering your friends' phone numbers, you probably do chunking

with the first three numbers. You are likely to have memorized the extensions in your area and need only to remember which extension it is. For example, in one community, all the extensions might start with "23": 231-, 234-, 235-, 237-, and 238-. If you already know these extensions, learning a new phone number only requires five chunks of information—the extension, and the four numbers following it. Your brain would see "234" as one chunk.

People who can seemingly remember more than seven items in their short-term memory have learned to use chunking very quickly and efficiently. They may be able to instantly join two pieces of information together to make one. For example, given a string of random numbers, they will join two at a time, remembering the list as a string of seven two-digit numbers, instead of fourteen individual numbers. They would also look for any patterns with significance for them: their age, a date in history, a friend's birth date, and so on, which could provide them with an instant mnemonic.

Another trick memory experts can use is tapping into the edge of long-term memory by using very fast repetition. We know that repeating something over and over again will transfer it from short-term to long-term storage. Those neuronal networks are reinforced each time the thought is repeated. With some practice, the experts can use those split seconds in between pieces of new information to reinforce the previous ones. For example, if you quickly repeat the whole string of numbers from the beginning each time a number is added, it might be just enough to get the first part of that string over into long-term territory. Of course, that doesn't mean you would remember those numbers for a long time. Some long-term storage only lasts for a few minutes or hours. If it is not reinforced again during this time, the memory will fade.

Why do some people have better memories than others? Do they have more glial cells in their hippocampus? Do they have more dendrites per neuron, or more efficient synapses? Brain researchers do not know the answer. Some researchers are studying memory savants like Kim Peek and Daniel Tammet to see how their brains process information. (Daniel Tammet memorized the value of π (3.1415...) to 20,000 decimal places!) So far, there is no sure answer as to what exactly goes on inside their brains. What we do know is that each one of us has more brain potential than we will ever use. There is nothing more complex and more amazing than a human brain, including yours!

* * * *

3) You have just entered a museum. What do you do?
   a) Find the information booth and get a map
   b) Go over to a museum staff person and ask advice about where to go first
   c) Strike out in any direction and rely on your sense of direction to guide you

4) Which would you be most likely to do if something exciting happened to you?
   a) Tell someone else then watch their face to see the reaction
   b) Tell someone the whole story of why I am happy, even if it takes a few minutes
   c) Jump up and down, nod my head, make gestures with my ams or hands, etc.

5) Of these options, which do you prefer?
   a) Read a story all by myself
   b) Listen to someone read the story to me out loud
   c) Act out the story in a drama

6) If you are trying to study or concentrate, which do you find most annoying?
   a) Things or people I see in the room out of the corner of my eye
   b) Noises in the room
   c) Feelings inside myself such as hunger, thirst, shoes are too tight, itchy sweater, etc.

7) If you are trying to remember how to spell a word, what do you do?
   a) I would write the word several ways and see which one looks right
   b) I would sound it out or spell it out loud
   c) I would write the word several ways and see which one feels the most familiar

8) If you had to learn how an engine works, which you would rather do?
   a) Read a book and look at diagrams
   b) Have someone explain it to me
   c) Tear one apart and figure out how it works as I go along

9) Of the following subjects, which one are you best at? If more than one, go ahead and circle any that apply.
   a) Art
   b) Music
   c) Sports

10) When you listen to a song, which of these is most true?
   a) I see pictures in my mind. The song reminds me of places I've been or people I know.
   b) I hum along and I know I will be able remember the melody for a quite a while.
   c) The rhythm is the most important part of the song. I would probably tap my foot or dance.

11) Of the following choices, which one is the worst? (Which would be the most difficult for you, personally?)
   a) Going blind
   b) Going deaf
   c) Being paralyzed

12) Of these choices, which book would you prefer?
   a) A book about another country that has a lot of photos and maps
   b) An autobiography where the author tells stories of his or her childhood
   c) An activity book that recommends that you try the things they describe for yourself

13) Of the following options, which one is the worst?
   a) A house with orange countertops, green carpet, brown furniture, and blue wallpaper
   b) A house where the television and stereo are always blaring too loud

c) A house with uncomfortable chairs and a temperature that is always too hot or cold

14) When you were younger, which activity would you have enjoyed the most?
   a) "I spy with my little eye..." or a scavenger hunt where you look for hidden items
   b) Listening to Mother Goose rhymes
   c) Playing "London Bridge" or "Ring Around a Rosy"

15) If you went to a lecture and wanted to remember what the speaker said, what would you do?
   a) Spend most of my time looking at the speaker, but take a few notes
   b) Listen intently, maybe even closing my eyes to concentrate
   c) Write down as many notes as possible, and doodle on the page if there is nothing to write

16) If you could do ONLY ONE of the following to learn a spelling word, which would be your choice?
   a) Look at the word for 30 seconds
   b) Listen to someone spell the word over and over till the 30 seconds are up
   c) Look at the word, then write it as many times as possible in 30 seconds

17) Which of these is easiest for you to remember?
   a) Faces
   b) Names
   c) Dance steps

Now score your results.
Number of a's you circled: _____ Number of b's: _____ Number of c's: _____

If you have more a's than anything else, chances are you're a visual learner. If you have more b's, you are probably an audio learner. If you have more c's, it is likely that you are a kinetic learner. If you have two or more with equal scores, that would suggest that you have two learning modes that are equally strong.

Remember, though, everyone uses all three of these learning modes at least some of the time. It's only a matter of which one suits you the best. (Please note that this survey cannot be used to officially diagnose anyone. It's just a silly survey.) Also, the younger you are, the less helpful surveys like this will be. Every year that you are alive adds to your life experience and your knowledge of yourself.

ACTIVITY 7.6 Categorize these memories

Put a check on the line that best describes each type of memory. Remember, implicit memory is in the cerebellum and is also called procedural memory. Episodic memory is tied to a certain event and semantic memory is made of facts you know whether or not you remember learning them. A few of these could have more than one right answer, depending on your life experience.

	Implicit (procedural)	Explicit (episodic)	Explicit (semantic)
The phone number of Carlo's Pizza	_____	_____	_____
The feel of my dog's fur	_____	_____	_____
3x3=9	_____	_____	_____
My math lesson from last week	_____	_____	_____
How my yard looks in the winter	_____	_____	_____
How to tie my shoe	_____	_____	_____
How to do a certain dance	_____	_____	_____
Where the Hawaiian Islands are located	_____	_____	_____
How my bedroom looks right now	_____	_____	_____
How to type on the keyboard without looking	_____	_____	_____
How to spell the word "brain"	_____	_____	_____
Don't mix peppermint with Cola-- yuck!	_____	_____	_____
I must be home by 9:00 PM	_____	_____	_____
How to zip a zipper	_____	_____	_____
The nursery rhyme "Humpty Dumpty"	_____	_____	_____
My homework assignment for tomorrow	_____	_____	_____
The dog next door bites	_____	_____	_____
What I got for my birthday last year	_____	_____	_____
The fact that birds can fly	_____	_____	_____
How to sign my name	_____	_____	_____

ACTIVITY 7.8 A word puzzle

Fill in the correct answers to these clues, then match the corresponding numbers underneath to the letters in the answer to the question below.

1) This is when your brain puts several small bits of information together to make one larger whole.

___ ___ ___ ___ ___ ___ ___ ___
11 3 15

2) This type of memory is based in your cerebellum, instead of your cerebrum.

___ ___ ___ ___ ___ ___ ___ ___
1 6 12 20

3) This is another name for the type of memory in 2).

___ ___ ___ ___ ___ ___ ___ ___ ___ ___
10 16 18 5

4) This type of memory contains specific events that happened to you.

___ ___ ___ ___ ___ ___ ___ ___
2 13 22 21

5) This type of memory contains facts that are not linked to a specific memory.

___ ___ ___ ___ ___ ___ ___ ___
9 23 4

6) This type of memory includes both the categories listed in 4) and 5)

___ ___ ___ ___ ___ ___ ___ ___
8 19 17

7) The short-term memory can only hold about this many pieces of information.

___ ___ ___ ___ ___
7 14

QUESTION: What are the two most important factors in determining how well the brain keeps its memory ability as it gets older?

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
1 2 3 4 5 6 7 8 9 10 11 12 13 14

and ___ ___ ___ ___ ___ ___ ___ ___ ___
15 16 17 18 19 20 21 22 23

Doctors now recommend that elderly people learn new skills.

CHAPTER 8

HOW THE BRAIN CONNECTS TO THE BODY

The brain and the spinal cord make up what is called the ***central nervous system***. All the other nerves outside the brain and spinal cord are referred to as the ***peripheral*** *(per-IF-er-ul)* ***nervous system***. Peripheral means "around the outside." The peripheral nerves include your five senses, the nerves that control the movement of your muscles, and some automatic body systems that we will learn about in this chapter.

This chart shows the parts of the nervous system and how they are organized into groups. We've already mentioned the first division, into the central nervous system (CNS) and the peripheral nervous system (PNS). The central nervous system is just the brain and the spinal cord.

All peripheral nerves are either ***sensory*** nerves or ***motor*** nerves. As the word sensory suggests, the sensory nerves are the ones found in your five senses: sight, hearing, taste, smell, and touch. The motor nerves control muscles, both the muscles that you can move voluntarily, like your arms and legs, as well as the ones that you don't have to think about, like the muscles in your heart and your intestines.

You are well acquainted with your ***voluntary*** muscles because you have direct control over them. You tell your motor cortex to send out signals to the voluntary muscles in your arms, telling them to move a certain way. You are not as familiar with your ***involuntary*** *(autonomic)* muscles because they function automatically—you don't have to think about them. Your heart beats, your diaphragm contracts, your stomach churns, your intestines push food along, the pupils of your eyes get larger and smaller, your saliva glands squeeze out saliva, and your blood vessels tighten or relax to adjust your blood pressure. You aren't even aware you are doing these things because your autonomic system just takes care of it all for you.

The ***autonomic*** part of the nervous system can be divided into two categories: ***sympathetic*** and ***parasympathetic***. The names of these categories might be hard for you to remember because they don't seem to have a whole lot to do with the function of these muscles. From the name "sympathetic," you might guess that these muscles are compassionate and feel sorry for other muscles (maybe ones you used too much the day before), since "sym" means "with" and "pathos" means "suffering." A better definition for our purposes

would be “with great passion or excitement.” This is the body system that gears you up when you need to be alert. The sympathetic nerves tell all their muscles to speed up. This makes your heart beat faster and your breathing rate increase. Your adrenalin glands start pouring adrenalin into your bloodstream. You begin to sweat, your mouth goes dry and the pupils in your eyes open up wider. Your muscles feel all tingly and ready for action because of the adrenalin. This is exactly what your body needs for some situations. Any time there is an emergency, your body flips the switch and turns on the sympathetic system. You are ready to go!

After the emergency is over, you body wants to return to normal. You can’t be on “red alert” all the time. The system that turns off the sympathetic system is called the parasympathetic system. “Para” means “against.” The parasympathetic system slows down the heart and breathing rates and calms the muscles, getting the body back to normal. The pupils in your eyes get smaller, you begin to salivate again, and you stop sweating. The parasympathetic system also helps you to recover after exercising.

The colored dots on the spine present groups of vertebrae that we give certain names. (There aren’t really any blank spaces between these groups; the artist chose to space them out so all the pictures on the sides would fit on the page.) “C” stands for “cervical” (neck), “T” is for “thoracic” *(thor-RASS-ik)* (chest), “L” is for “lumbar” (low back), and “S” is for “sacral” (the end of the spine). The lines represent nerve fibers that come out of the vertebrae at these places and go to the organ(s) indicated.

What do these nerves look like? What is a nerve fiber? The diagram on the left shows that a nerve is made of bundles of bundles of bundles. The smallest units are the individual axons of the neurons. The axons are bundled into long units called ***fascicles*** *(FASS-ik-uhls)*. The fascicles are then bundled into the units we call ***nerves***. Each bundle, both the fascicles and the nerves, are covered with a layer of connective tissue, (the same stuff that you find in ligaments and tendons).

All the axons in a fascicle belong to nerves that have similar functions; they might all be headed to your right hand, or to the smooth muscles in your intestines.

Now, let's take a look at a slice, or cross section, of the spinal cord. (This picture does not show the bone [vertebra] around the spinal cord.) The inside of the spinal cord is made of gray matter and white matter, just like the brain. In the spine, however, the pattern is reversed, with the white matter on the outside and the gray matter on the inside. (Remember that gray matter is mostly cell bodies and white matter is mostly axons.) The hole in the center of the cord, the ***central canal***, is an extension of the ventricles (fluid-filled spaces) in the brain. The canal runs from the bottom of the brain to the bottom of the spine.

The neurons in this diagram are drawn much larger than they should be, so that you don't need a microscope to see them. The muscle represents any muscle of the body. Notice the synaptic knobs and the dendrites touching the muscle. The knobs are transferring the electric signal to the muscles, and the dendrites are picking up information to send back to the brain. "Inter-neurons" inside the gray matter connect neurons to other neurons, and carry the signal up to the brain. Notice that the neurons carrying signals out of the spine are located on the front side, and the neurons carrying signals into the spine are located on the back side. This holds true all the way up and down the spine.

The ***vertebrae*** protect the spinal cord and prevent the neurons from being damaged. The holes in the vertebrae (shown by **red dot** in vertebra below) line up so the spinal cord can go down through them. There are small gaps between the vertebrae where bundles of nerves can get out (shown in green). There is padding in between the vertebrae bones so they don't rub together. It's amazing how much your back can twist and flex and bend without hurting the nerves!

Here's a drawing of a vertebra that Andreas Vesalius did way back in the 1500's. (Remember Vesalius from chapter 1?!)

A very important safety feature programmed into your peripheral nervous system is the ***reflex***. A reflex allows your body to react to dangerous situations with lightning speed. Every millisecond counts when you do something like accidentally touch a hot stove, so your peripheral nerves don't even take the time to send a message to the brain before they react. It's much faster to go just to the spinal cord and back. The peripheral nerves take care of the situation right away, then send a signal to your brain to notify you of what just happened.

Other types of reflexes include blinking, sneezing, gagging, vomiting, yawning, grasping and scratching. The reflex in your knee that doctors sometimes check is called the *patellar* reflex (the patella is the name of your "knee cap"). When the doctor hits the patellar tendon under the knee cap, this stretches the tendon a tiny bit. The tendon pulls on the muscles in your leg, which then send a signal to the reflex area of your spinal cord. The spinal cord sends an instant signal back telling the muscles in the leg to contract a little bit, to compensate for being stretched. This tightening results in your lower leg "kicking" (just a very small amount). Sometimes this reflex is called the *knee-jerk response*.

A reflex you use all the time without knowing it is the ***pupillary reflex***. The pupil in your eye has a muscle around it so that it can make the hole larger or smaller, depending on how much light is available. In low light the pupil opens up to let in as much light as possible. In bright light, the pupil shrinks and becomes very small because too much light will damage the retina at the back of the eye. Your pupils are constantly adjusting to levels of light all day long as the light around you changes.

ACTIVITY 8.1 Reflex word search

Use these clues to find reflexes in the word search puzzle. The words in the puzzle may go up, down, diagonally, or backwards.

1) This reflex keeps your lungs and bronchial tubes clear.
2) This reflex brings things up that were not supposed to go down.
3) This reflex is a palindrome: it spells the same backwards and forwards.
4) This reflex is designed to relieve an itchy feeling.
5) This reflex keeps your nose clear of dust or other irritating substances.
6) This reflex is what you do if you suddenly feel like you are falling.
7) This reflex keeps your eyes safe.
8) This reflex is "contagious" and if you see someone else do it, you might do it, too!
9) This reflex is the main one doctors check.

C	F	M	Y	H	L	T	H	B	L	Y	M
E	Z	E	E	N	S	W	C	L	R	A	R
N	D	O	R	L	N	V	T	I	R	W	O
B	X	G	A	G	P	S	A	R	G	N	P
I	L	S	H	J	L	S	R	M	F	T	F
J	T	I	M	O	V	I	C	O	U	G	H
O	R	W	N	T	U	D	S	P	L	R	H
M	F	S	L	K	H	O	Z	N	G	D	L
E	S	P	A	T	E	L	L	A	R	E	Y

ACTIVITY 8.2 Watch your pupillary reflex

Look into a mirror. Notice the size of your pupils. Now put your hands over your eyes to give them total darkness. Don't press on your eyeballs. After about 30 seconds or so, uncover your eyes and look into the mirror right away. Watch your pupils. They should go from large to small very quickly. You can repeat this experiment as many times as you want to. If you have someone to be your partner, you can watch each other's pupillary reflexes.

ACTIVITY 8.3 True or false questions

Put a T or an F beside each statement. Use the diagram on page 67 to help you.

1) All motor nerves are peripheral nerves. ____

2) Both voluntary and involuntary muscles are controlled by motor nerves. ____

3) The peripheral system is part of the central nervous system. _____

4) The sensory nerves are part of the autonomic (involuntary) system. ____

5) Both sympathetic and parasympathetic nerves are part of the involuntary system. ____

6) The brain and the spinal cord are both part of the central nervous system. ____

7) Sympathetic nerves are part of the peripheral system. ____

8) All motor nerves are peripheral nerves, but not all peripheral nerves are motor nerves. ___

9) All sympathetic nerves are involuntary, but not all involuntary nerves are sympathetic. ___

10) Both sympathetic and parasympathetic systems are motor nerves. ___

ACTIVITY 8.4 Write about a time your sympathetic system turned on suddenly

Write about a time when your sympathetic system turned on very quickly. Did a large dog frighten you? Did you get scared during a movie? How did you feel, and how long did it take to feel okay again?

CHAPTER 8.5

MORE ABOUT HOW THE BRAIN CONNECTS TO THE BODY

The spinal column is important to the brain because it protects all the nerves that connect the brain to the body. Most people have 33 vertebrae, although rarely someone is born with 32 or 34. It's not harmful to have more or less than 33, just a little unusual. Most people who have 32 or 34 are unaware of it. Rarely do doctors think to count vertebrae.

The top seven vertebrae, which make up the neck, are called the ***cervical*** *(SER-vik-ul)* vertebrae. (FUN FACT: Almost all mammals have seven cervical vertebrae, no matter how long or short their neck is. Even a giraffe has only seven.) The top two cervicals, right under the skull, have special names. The very top one is called the ***atlas*** because it bears the weight of the skull sitting on top of it, just like the mythological character Atlas who was said to carry the Earth on his shoulders. Under the atlas is the ***axis***. It allows the skull to rotate on top of the neck. The other cervical vertebrae are just known by numbers: C3, C4, C5, C6, and C7.

The next section of vertebrae are ***thoracic*** *(thor-RASS-ik)*. The numbers start over again, so these are numbered T1 to T12. (They are actually vertebrae #8- #20.) From the thoracic vertebrae come all the nerves that go to the heart, lungs, stomach, and other organs in your chest. The ***lumbar*** vertebrae are numbered L1 to L5. Their nerves go out to the lower back and legs. Below the lumbar, are the ***sacral*** vertebrae. On the very bottom, the last few vertebrae are permanently stuck together to form the ***coccyx*** *(COK-sicks)*.

Notice the little pads between the vertebrae. They are called ***discs***. If a disc slips out of place it can be very painful and might require surgery to put it back. Fortunately, the discs are anchored securely and rarely slip out.

If the vertebrae get out of line, they can pinch the nerves that stick out of them. Doctors who have been trained to push the back into place are called ***chiropractors***. "Chiro" means "hand." Chiropractors push and pull the spine with their hands. Sometimes they use other treatments, as well, such as massage or physical therapy exercises.)

Bundles of nerves go from the spinal cord out to all parts of the body. As we have mentioned previously, some of these nerves are sensory nerves, which are busy sending signals back to the brain telling it what is going on, both in your body and in the environment around you. Each sense has a special kind of nerve ending. The nerve endings at the back of your eyes (in an area called the retina) are designed to sense photons of light. The nerve endings that sense light can't sense pain, heat, sound or taste. The nerve endings in the nose can sense only odor, nothing else. Those in the ear can sense only sound. Probably the most interesting-looking nerve endings are found in the skin. There are five different types, each one able to sense only one thing.

The five types of nerve endings in your skin sense ***pain, light pressure, deep pressure, heat, and cold.*** Notice that the nerve endings for pain look unprotected (ready to "scream" if anything touches them), whereas the pressure receptors have padding around them. There are also lots of other things in the skin, as you can see.

The sensory nerve cells in the eye are called ***rods and cones***. The rods sense light, but not color. The cones can sense color, but need sufficient light to function. When the light is dim, your cones don't work, but your rods can see shades of gray. Thanks to your rods, you can see well enough at night to be able to make your way to the bathroom without bumping into the walls.

Intermediate cells transfer light signals into electrical signals that are sent to the brain. The main nerve that takes the information to the brain is the ***optic nerve***.

Diagrams of the nerve endings in the nose and tongue don't look quite so complicated:

taste bud on tongue

The nerve endings in both the nose and mouth are designed so that certain types of molecules will stick to certain of the receptor cells, causing those cells to fire off a signal to the brain. There are extremely small hairs (not the nose hairs you can see in your nose) in the sinuses that aid the nerve endings in picking up signals.

There are also microscopic hairs in the ear that help the auditory nerve endings. Deep inside the ear, behind the ear drum, in the ***cochlea*** *(KO-klee-ah)*, these microscopic hairs help to transfer sound waves to the nerve endings. The pressure of the sound waves moves the hairs, which "tickle" the nerve endings, causing them to send electrical signals to the brain. The nerve that carries sound information to the brain is the ***auditory nerve***.

Here's a bizarre, but interesting, question: What would happen if the neurons taking in sound from your ears went to the vision center in your occipital lobe, instead to the sound center in your temporal lobe? Would you see sounds? What if the nerve endings in your eyes were wired to your temporal lobe? Would you hear colors? Yes, you probably would!

It was once thought that "mixed up wiring" is what causes an unusual condition known as ***synesthesia*** (*SIN-es-THEE-zhee-uh)*. People with this condition seem to have sensory input going to the wrong parts of the brain, as they report experiences such as seeing sounds, hearing or smelling colors, or tasting words. A famous painter named Kandinsky always said that he could "hear the colors in his paintbox hissing."

Recent research has revealed that it is unlikely that sensory nerves are actually wired to the wrong lobes. Certain drugs and medicines can cause temporary synesthesia that goes away within a few days. The wiring in your brain can't change that fast. So a new hypothesis was needed to explain what was going on. We know that each brain part is connected to every other brain part in some way. Some of these connections are direct and strong (such as between the frontal lobe and the motor cortex) but others are supposed to be indirect and not very strong. Synesthesia might occur when connections that are supposed to be weak become too strong. Another line of evidence supporting this hypothesis comes from the realm of language, and our ability to use analogies. We say that cheese tastes "sharp." The color red evokes feelings of danger or excitement. Words like "oval" and "blue" sound soft, whereas words like "cut" and "people" sound hard. To use analogies, brain parts have to share a little bit of information. This type of weak connection is normal. It is possible that in synesthesia, these normal connections are just too strong.

There are different types of synesthesia. For some people, words or numbers to appear colored, even though they are printed in black and white. One person reported that the number five is bright red, whereas the number two is yellow. Others say that certain words give them taste sensations. One person said that reading the name "Lori" tasted like a pencil eraser, whereas reading the name "Laurie" tasted like lemon. The artist Kandinsky saw music as colors and shapes. His paintings were often pictures of what he saw when he listened to a particular piece of music. For other synesthetes, tastes evoke colors. One man reports that chicken tastes light blue. When he cooks, he matches colors as well as tastes.

"Yellow-Red-Blue" by Wassily Kandinsky, 1925

* * * *

CHAPTER 9

SLEEP

What happens when we sleep? Why do we need to sleep? Why do we dream? These questions are still being investigated by brain researchers, using "sleep labs." Volunteers agree to spend a whole night in a sleep lab, with wires taped to their head. The wires pick up the electricity their brain produces as they sleep, and a machine displays this electricity as wavy lines on a chart. (More recently, the wavy lines are on a computer screen, not a paper chart.) The name of this machine is the ***electroencephalograph*** (ee-LECT-ro-en-CEFF-al-o-graf) abbreviated as either ***EEG*** or ***ECG***. (*Electro*= electricity, *en*= in, *cephalo*= head, *graph*= picture.)

This is an old-fashioned machine that uses paper and a pen.
Most scientists use computers now, and just print out the results.

In the morning, the researchers can look at the complete record of what the brain did all night. The squiggles on the chart might look something like this:

Looking carefully at the squiggly patterns, scientists have determined that brains make four basic types of wave patterns. They decided to name these four patterns after four letters in the Greek alphabet: ***alpha, beta, theta, delta***. In English, it might be like calling them A, B, C, D, (except that theta represents "th," not "c"). When you are wide awake your brain makes ***beta waves***. They are the smallest and shortest waves. As you start to get drowsy, your brain begins to make ***alpha waves***. You also make alpha waves if you are peacefully daydreaming or doing something very relaxing. Gradually, those alpha waves begin to turn into ***theta waves***. This is when you are actually dropping off to sleep. Finally, you go into deep sleep and produce ***delta waves***. Your heart rate and blood pressure drop. You are fast asleep. You might think that this is the end of the story—that you make delta waves until you wake up. But, no, your brain has just begun!

After you have been asleep for about an hour or so, your brain starts making waves that are similar to the ones you make when you are awake. During this time, your eyes move back and forth rapidly, so this stage of sleep is known as "Rapid Eye Movement," ***REM***. It is during REM that you dream. After a period of REM, you go back into deep delta waves for a while. You alternate periods of REM and delta waves until you wake up. A typical night may have four or five periods of REM.

There are many theories about why we dream, but no one knows for sure. Some scientists say that our brain is doing something similar to defragging a computer—sorting and storing all the data it has taken in during the day. Other scientists think our brain is just firing off neuronal networks at random, and our poor frontal lobe has to try to make sense of all the thoughts and tie them into some kind of story line. Some psychologists theorize that our dreams are how we deal with fears and anxieties. All of these could be true. Whatever the purpose of

dreams, it is definitely true that your brain uses bits and pieces of memories stored in the neocortex. If you decide to watch a scary movie, just remember that it will become a permanent part of the available material your brain has to work with when it creates dreams!

We all know that feeling of "it's time to go to bed." Our bodies have a natural rhythm of waking and sleeping. This rhythm is known as the ***circadian*** *(sir-CADE-ee-un)* ***rhythm***. "Circa" means "cycle" and "dia" means "day." An interesting study was done in Germany to determine what the natural human circadian rhythm would be if there were no sunrise, no alarm clocks, and no one to tell us to go to bed. Volunteers agreed to spend an entire month underground, with no clocks and no sunlight. They had lamps they could turn on when they wanted light. They ate and slept whenever they felt like it. All during this time, they wore brain wave monitors that kept track of when and how much they slept. The results of the study indicated that, if left to our own devices, humans would prefer to have a daily cycle of 24.6 hours, not 24 hours. We really would go to bed a little later every night if we could get away with it! Life brings us extra tiring days every once in a while, which help tire us early and reset our circadian clocks.

Research with rats has suggested that the hypothalamus plays an important part in circadian rhythm. It is linked to both the optic nerve and the pons. The pons is the actual alarm clock that brings you to consciousness, but the hypothalamus helps to determine how many hours of sleep you need, and whether you are a "night owl" or a morning person. The link to the optic nerve is to help your brain be awake when it is light and asleep when it is dark. We also learned about the pineal gland in a previous chapter. This gland is connected to special cells at the back of your eye. The pineal gland is most active when it is dark, producing the hormone ***melatonin***, which helps us to sleep. Young children produce twenty times as much melatonin as adults do, which is why babies "sleep like babies."

* * * *

CHAPTER 9.5

MORE ABOUT SLEEP

Let's take a closer look at the waves the brain makes while sleeping. There are five stages of sleep.

Stage 1 is made of theta waves and occurs when you are falling asleep. During stage 1 you are vaguely aware of sounds around you, and your muscles may twitch. (On rare occasions, one of your muscle twitches might be strong enough to jolt you awake again.) **Stage 2** begins when your theta brain waves start making patterns called ***spindles***. No one really knows what these spindles do, but we know that during stage 2 you are no longer aware of your environment; you become completely unconscious. **Stage 3** begins when your brain starts making delta waves. Stage 3 doesn't last very long and functions mostly as a transition into **stage 4**. Your deepest sleep occurs during stage 4. This is when you are the most difficult to wake up. It is also the stage during which events such as sleep-walking, sleep-talking, bed wetting, and night terrors occur.

Stage 5 is REM sleep, when your eyes move rapidly back and forth (Rapid Eye Movement) and your brain waves resemble the type you make when you are awake. Your frontal lobe and motor cortex are busy sending signals during REM sleep. You would actually get up and do what you are dreaming about if it were not for a special function of the brain stem in which it stops the production of one of the neurotransmitters necessary for the muscles to receive the signals. The electrical signals come to the synapses and stop. There are no chemicals there to transfer the signals across the gap. Therefore, the muscles don't ever receive the messages.

REM sleep is when most of your dreaming occurs. Scientists used to think that dreaming occurred exclusively during REM, but sleep labs now report that they have recorded periods of dreaming during all stages of sleep. During the last three hours of your night, you spend more time in REM sleep than any other stage. It is during this time that you have the dreams you will remember when you wake up. People who claim they don't dream just don't remember what they dreamed. If they were tested in a sleep lab, their brains would show the same pattern of REM that everyone else's does.

During the night, your brain goes through the stages of sleep four or five times. If you wrote down all the stages (using the numbers in the diagram above), the series of numbers might be something like this:

1 2345 2345 2345 2345 2345 1

WHAT IS A NIGHT TERROR?

Night terrors aren't the same as nightmares. Nightmares are scary dreams produced during REM sleep. Night terrors occur during non-REM sleep, usually just an hour or two after falling asleep. The person may look awake, but will be seeing and hearing things that aren't real. Often, what they see and hear is frightening to them, and they may yell or cry. It can be distressing to watch someone having a night terror. You won't be able to wake them up out of it, though, and trying to wake them up will only make things worse. The best thing to do is to get them to lie back down and go back to sleep. In the morning they won't remember a thing about it!

If you are awakened too many times during the night and you can't complete enough "2345" cycles, you will probably feel drowsy and tired the next day. If the brain is deprived of REM time, it will go into REM more quickly the next night.

A condition called ***sleep apnea*** occurs when the airways (usually sinuses and/or throat) close up and the brain has to wake up the body to correct the problem. As soon as the person is a awake, the airways go back to normal, but when they fall back asleep, it happens again. To correct this, doctors often recommend using a special breathing apparatus that keeps the airways open.

* *

ACTIVITY 9.2 Do some REM observation

You may have already observed this, but if you haven't, it's a fun thing to do. Find someone who is taking a nap and watch their eyelids. If you are lucky you'll catch them in the middle of some REM sleep and you will see the eyeballs moving around under the eyelids. If they aren't in REM, wait a while and then come back and try again. (This works with dogs, too. Watch their eyes flutter around. Sometimes they softly bark or making running motions with their feet, too.)

ACTIVITY 9.3 Read a poem written while the poet was asleep

Samuel Taylor Coleridge was a poet who lived in England in the late 1700s. In the summer of 1797 he was in poor health and retired to a lonely farmhouse to get some rest. One day he took some medicine which made him drowsy, and he fell asleep in his chair just as he was reading the following lines in a book: "Here the Khan, Kubla, commanded a palace to be built and a stately garden thereunto. And thus, ten miles of fertile ground were enclosed within a wall." Coleridge slept for about three hours, during which time he had an incredible dream, so vivid and real that he almost could not believe his brain had been capable of making it up. While he slept, the lines of a poem came to him as if they were already composed and all he had to do was write them down. Upon wakening, he wrote down as much as he could remember. After a few minutes of writing, someone came and called him away from his desk. Upon his return to his desk he found that his memory of the dream had faded considerably. He did his best to patch together what he could in order to finish the poem.

Before you start reading, you will need to know what some of the words mean. Here is a list of the words that could possibly be unfamiliar to you.

sinuous: winding, wavy like a serpent
rill: a very small stream
athwart: across, in opposition to
cedarn: made of cedar
waning: decreasing in size; diminishing
chaff: lightweight debris blown off wheat seeds
thresher: person who beats (threshes) wheat seeds until the chaff separates and blows off
flail: tool used for threshing wheat
meander: to follow a wandering path
tumult: uproar or confusion
prophesy: to predict the future
dulcimer: a stringed musical instrument
Abyssinian: from Abyssinia, in Africa

"Kubla Khan" *by Samuel Taylor Coleridge*

NOTE: You can listen to a professional reader recite this poem on the YouTube channel. (If it's not there, just search using the title and author.)

In Xanadu did Kubla Khan
A stately pleasure-dome decree :
Where Alph, the sacred river, ran
Through caverns measureless to man
Down to a sunless sea.
So twice five miles of fertile ground
With walls and towers were girdled round :
And there were gardens bright with sinuous rills,
Where blossomed many an incense-bearing tree ;
And here were forests ancient as the hills,
Enfolding sunny spots of greenery.
But oh ! that deep romantic chasm which slanted
Down the green hill athwart a cedarn cover !
A savage place ! as holy and enchanted
As e'er beneath a waning moon was haunted
By woman wailing for her demon-lover !
And from this chasm, with ceaseless turmoil seething,
As if this earth in fast thick pants were breathing,
A mighty fountain momently was forced :
Amid whose swift half-intermitted burst
Huge fragments vaulted like rebounding hail,
Or chaffy grain beneath the thresher's flail :
And 'mid these dancing rocks at once and ever
It flung up momently the sacred river.
Five miles meandering with a mazy motion
Through wood and dale the sacred river ran,
Then reached the caverns measureless to man,
And sank in tumult to a lifeless ocean :
And 'mid this tumult Kubla heard from far
Ancestral voices prophesying war !
The shadow of the dome of pleasure
Floated midway on the waves ;
Where was heard the mingled measure
From the fountain and the caves.
It was a miracle of rare device,
A sunny pleasure-dome with caves of ice !
A damsel with a dulcimer
In a vision once I saw :
It was an Abyssinian maid,
And on her dulcimer she played,
Singing of Mount Abora.
Could I revive within me
Her symphony and song,
To such a deep delight 'twould win me,
That with music loud and long,
I would build that dome in air,
That sunny dome ! those caves of ice !
And all who heard should see them there,
And all should cry, Beware ! Beware !
His flashing eyes, his floating hair !
Weave a circle round him thrice,
And close your eyes with holy dread,
For he on honey-dew hath fed,
And drunk the milk of Paradise.

ACTIVITY 9.4 Read about two scientific discoveries made while the scientists were asleep.

A scientist named August Kekule *(keh-kyu-lay)* was a chemist who lived in the late 1800s. He had been working on the problem of how six carbon atoms and six hydrogen atoms could fit together to make the chemical compound "benzene." The rules of chemistry said that every carbon atom had to have four bonds, but hydrogen could only have one bond. Kekule experimented with every possible mathematical combination that could be made with these atoms, but nothing worked. It had been proven that there were six carbons and six hydrogens in benzene, but no one could figure out what the molecule looked like. Then, one night, Kekule fell asleep while thinking about the benzene molecule. He dreamed that he saw the chain of carbon atoms bend around and touch at the ends, to form a circle. When he woke up, he remembered the dream and realized that his brain had solved the mystery while he was asleep. The benzene molecule was not straight, as everyone supposed—it must be a ring! The ring structure was later proved to be correct.

Dmitri Mendeleev is know today as the inventor of the Periodic Table of chemical elements. The table is a rectangular chart with all the known elements listed in columns and rows. In Dmitri's day, only 63 elements were known. It was recognized that there were groups of three elements, called triads, that had very similar characteristics, but that was the extent of any organized patters. Dmitri make paper cards with the name of an element written on each one. He spent many days shuffling the cards around, looking for a pattern. One evening, after working relentlessly for two days straight, he fell asleep over his cards. He dreamed that the cards arranged themselves into a rectangle, with certain cards at the beginning of each line. When he woke up he tried the pattern he had dreamed and found that it seemed to be the correct solution.

ACTIVITY 9.6 ***A review so easy you could do it in your sleep!***

Can you still remember the answers to these questions?

1) Name the six basic lobes of the cerebrum: _____

_____

2) What does the medulla oblongata do? _____

3) What does the pons do? _____

4) Which brain part controls hunger and thirst? _____

5) The astrocyte and the oligodendrocytes are examples of _____ cells.

6) The vertebrae in the neck are called the _____ vertebrae.

7) The vertebrae numbered L1 though L5 are called the _____ vertebrae.

8) The nerve that connects the eye to the brain is called the _____ nerve.

9) The nerve that connects the ear to the brain is called the _____ nerve.

10) The nerves throughout the body are part of the _____ nervous system.

11) The brain and spine make up the _____ nervous system.

12) Is the sympathetic system part of the voluntary or involuntary system? _____

13) The thin protective membranes surrounding the brain and spine are called the _____

14) REM stands for _____ _____ _____

15) The pineal gland produces this hormone: _____, which helps you sleep.

16) Which brain waves do you produce while awake? Mostly _____ but maybe some _____.

17) When you are in your deepest sleep, your brain is producing which kind of wave? _____

18) How many stages of sleep are there? _____

19) Sleepwalking occurs when your brain is in stage ____.

20) What famous poet wrote a poem while he was asleep? _____

CHAPTER 10

BRAIN DOCTORS

There are many kinds of doctors. The doctors you go to see for check-ups and for treatment of common ailments such as sore throats and ear infections are called *general practice* doctors or *family practice* doctors. If you go to a doctor who sees only children as patients, he or she would be a *pediatrician* (the "pedia" part of the word means "child"). If one of these doctors thinks you may have a problem somewhere in your nervous system, they might send you to a doctor who deals only with nervous system problems: a ***neurologist***. If this doctor happens to treat only children, he or she would be a ***pediatric neurologist*.** The neurologist has a general knowledge of the body, just like the family doctor or pediatrician, but he or she stayed in medical school for additional years, studying just the nervous system. Any type of doctor who studies and treats just one kind of problem is called a ***specialist***. A neurologist is a specialist who specializes in the nervous system. Even in the field of neurology, there are specialists. Usually, they still call themselves neurologists, but add "specializing in [whatever]." (Informally they are sometimes called "super specialists.") Specializing in just one thing allows the doctor to take the time to learn everything there is to know about that one topic. For example, a neurologist might specialize in a disease such as epilepsy. This means they could spend all their time learning about just epilepsy, and become very good at diagnosing and treating it. They would see only patients with epilepsy.

If a nervous system problem requires surgery, the patient will be operated on by a ***neurosurgeon***. This type of surgeon specializes in operating on the brain and spinal cord. Some neurosurgeons specialize even more, and do nothing but brain surgery. (Dr. Ben Carson, mentioned back in chapter 6 was a pediatric neurosurgeon.)

Brain problems that do not affect the function of motor or sensory nerves, and do not require surgery, can often be handled by a doctor called a ***psychiatrist***. A psychiatrist is a medical doctor who specializes in brain disorders that affect mainly behavior, but also might include physical symptoms such as weight gain or loss, fatigue, or rapid pulse. A psychiatrist's office might not look like a typical doctor's office: no thermometers, no latex gloves, no exam table. The psychiatrist talks to his patients and listens carefully as they describe how they are feeling. They will determine if the patient might have a chemical imbalance in their brain that is causing the symptoms. If so, they might prescribe a medication. If not, they might refer the patient to another type of doctor, a ***psychologist***.

A psychologist cannot prescribe medicines. He or she simply talks with the patient and helps them find ways to change their thinking or their lifestyles in order to reduce the symptoms they are experiencing. For example, if the depression a patient is experiencing is not because of neurotransmitters, but is the result of difficult relationships with family members, the psychologist can help the person come up with ways of improving those relationships. Everyone has times in their life when they experience difficulty, and it can be very helpful to talk to someone during those times. Psychologists have been trained to know what to say and to know what advice to give. Sometimes a psychologist will talk to more than one person at a time. The whole family might need a group meeting with the psychologist in order to work out their differences. This is sometimes referred to as ***group therapy***.

One of the first scientists to do research in the field of psychology was ***Sigmund Freud***. Born in Austria, in 1856, Freud's theories about the workings of the human mind came to have a powerful impact on the whole world. He is best known for his theories about the unconscious mind and how it can repress (intentionally forget) bad memories. He believed that dreams are very important and can be used to diagnose mental problems.

He was one of the first doctors to encourage patients to talk openly about their thoughts, feelings, and memories. He might get the conversation started by asking the patient what they dreamed last night, then he would let the patient ramble on about anything they had on their mind. He called this "free association." As Freud listened to them talk, he would be thinking of possible reasons for the patients' thinking patterns. He would often see problems in adulthood as being related to experiences the person had as a child.

Some of Freud's theories were good, and others were pretty crazy. Most of Freud's ideas are not taken seriously anymore, but in the first part of the 19th century, his opinions ruled the world of psychology. Freud became so famous that even today almost all cartoon caricatures of psychologists, are based on Freud.

* * * *

Just for fun, here is an ink blot test we made up. What do you see in each blot? After taking it yourself, you might want to have several other people try it and see how their answers compare to yours. Remember, there is no right answer. Whatever you see is your right answer. Each person's brain has its own interpretation.

ACTIVITY 10.2 Phobias

We all have fears. Some fears are good and they keep us safe. Being afraid of lightning and thunder keeps us from walking out into a storm and getting hit by a lightning bolt. But if our fears get out of control and become so strong that they are no longer helpful, we call them ***phobias***. For example, someone who has a phobia of spiders doesn't just avoid them while gardening—they might refuse to go into a house just because they saw a tiny spider crawl past the front door two weeks ago! A phobia of large animals might make it impossible for you to visit a zoo or take a walk in the woods.

If you want to get rid of a phobia, you might go to a psychologist for help. One technique the psychologist might use is called *desensitization,* a process by which you gradually build up a level of tolerance for what you are afraid of. If you are afraid of dogs, you might start by just saying the word "dog." Once you feel comfortable with that, you might move up to looking a picture of a dog. When you are okay with looking at the picture, you might look at a real dog, but from far away. Bit by bit, you would take little steps closer to being able to be right next to a dog without being afraid.

Scientists love to come up with complicated names for things, and psychiatrists and psychologists are no exception. There is a fancy name for almost any fear you can think of. Most, but not all, of the names come from Greek or Latin. See if you can match the phobia name on the left its description on the right. Use any knowledge you have of other words that look or sound similar. (For example, where have you seen the word "dendro" before? Do you know what a "feline" is? What other words do you know that have "hydro" in them?) Good luck!

1. ____ achluophobia
2. ____ acrophobia
3. ____ amnesiophobia
4. ____ androphobia
5. ____ apiphobia
6. ____ arachnophobia
7. ____ autophobia
8. ____ bacteriophobia
9. ____ bibliophobia
10. ____ brontophobia
11. ____ claustrophobia
12. ____ cleptophobia
13. ____ dendrophobia
14. ____ entomophobia
15. ____ felinophobia
16. ____ hemophobia
17. ____ hydrophobia
18. ____ lilapsophobia
19. ____ logizomechanophobia
20. ____ olfactophobia
21. ____ polyphobia
22. ____ pyrophobia
23. ____ sesquipedalophobia
24. ____ toxiphobia
25. ____ triskaidekaphobia
26. ____ xenophobia

A. fear of being alone
B. fear of poison
C. fear of the number 13
D. fear of computers
E. fear of heights
F. fear of blood
G. fear of strangers
H. fear of more than one thing
I. fear of fire
J. fear of men
K. fear of the dark
L. fear of cats
M. fear of bees
N. fear of trees
O. fear of small, closed-in spaces
P. fear of bad smells
Q. fear of water
R. fear of things being stolen
S. fear of getting amnesia
T. fear of spiders
U. fear of thunder and lightning
V. fear of insects
W. fear of hurricanes and tornadoes
X. fear of germs
Y. fear of books
Z. fear of long words

CHAPTER 10.5

BRAIN PROBLEMS

NOTE: This chapter is optional. If reading about diseases is distressing, skip it.
You can always come back to it later if you need the information.
However, there is nothing gross, graphic, or inappropriate—have no fear!

Like any part of the body, the brain can get sick of sustain various types of injuries. Now that you know a bit about how the brain works, you might be able to predict some of these problems. Any part of the system could malfunction: the neurons, the glial cells, the myelin insulation on the axons, the blood-brain barrier, the blood supply to the cells, the synapse gaps between the cells, etc. Let's take a look at a few common problems and see what doctors can do to fix them.

The most common problem associated with the head is a ***headache***. The brain, however, has no pain sensors at all—it *can't* hurt. So what hurts when you have a headache? It sure feels like your brain is hurting sometimes. Since it can't be the brain, it has to be the tissues surrounding the brain. There is a massive network of blood vessels around and below the brain, and if these vessels suddenly enlarge this can result in a sensation of pain. (Some migraines fall into this category, but some don't.) There are medicines that can shrink the blood vessels a bit so the throbbing sensation goes away. Even caffeine will sometimes achieve this, so some people will drink a cup of coffee to cure their headache. ***Migraines*** are headaches that usually occur on one side of the head and often come with other symptoms, too, like dizziness, feeling nauseated, or sensitivity to light. Migraines can have any number of causes. Usually there are specific "triggers" that get them started. Common triggers include foods, stress, exercise, bright lights, or changes in the weather. Migraines, as well as other types of headaches, can also be caused by injury to, or misalignment of, the cervical vertebrae.

Other types of headaches hurt because of tightness in the muscles of the neck or eyes. Medicines like aspirin, acetaminophen or ibuprofen stop the sensation of pain by interfering with the process of pain signals being sent to the brain. If the brain never gets the pain signals, the result is that you don't "feel" the pain. Headaches can also be caused by food sensitivities and allergies, sudden drops in blood sugar, and, rarely, brain tumors. People who don't know the causes of their headaches can be greatly helped by ***functional medicine*** or ***integrative medicine*** doctors. This type of doctor likes to play detective and figure out what is going on. They take everything into consideration, including your diet, your environment, your genetics, your activity level, and even your relationships. They will prescribe medicines if necessary, but will first try to figure out what is causing your headaches and if there is a way to stop them by making changes to lifestyle or diet.

If you smack your head against something, you might get a ***concussion***, which is sort of like a bruise in the brain. Microscopic blood vessels (capillaries) can break, allowing blood to seep out. For a mild concussion, there isn't much you can do. You just rest a bit, then make sure it doesn't happen again. Those glial cells will get to work and clean up the mess. For a severe head injury, doctors may need to drain off extra blood and fluids so they don't cause too much pressure inside the skull. You can do a lot to prevent severe head injuries by wearing safety devices such as helmets and seat belts.

If the neurons in the brain make too much electricity, an "electrical storm," will result. In the disease called ***epilepsy***, one part of the brain suddenly starts producing way too much electricity, causing a ***seizure*** (see-zhure). There are different types of seizures, depending on what part of the brain is sending out the signals. A seizure can be hardly noticeable—the person just sits and stares blankly for a few seconds— or it can be very severe, causing the person's whole body to twitch and jerk. A seizure can be as short as few seconds, or as long as an hour. Most last a few minutes. Seizures can happen as often as several times a minute or as rarely as a few times a year.

If a neurologist suspects that a person might have epilepsy, they order an ECG test. (This is the same machine we learned about in the chapter on sleep.) Electrodes are taped to the head at various places and the patterns of electricity put out by the brain are recorded as squiggly lines on a graph. If the person has a seizure, it will show up as spiky lines on the graph, going both higher and lower than the regular squiggly lines.

The most common treatment for epilepsy is medicine that stops the brain from making so much electricity. These drugs are called ***anti-convulsants.*** (To "convulse" means to have a seizure). Most people with epilepsy find that these medicines work very well, allowing them to live normal lives. In very rare cases, surgery can help. This was the case with the "split brain" patients we learned about in chapter 3.5.

The most common brain problem in older people is called a ***stroke***. We mentioned this brain injury way back in chapter 1.5, when we learned that brain injuries were a key to learning the function of brain parts. When someone has a stroke, one of the blood vessels in their brain becomes blocked by a blood clot, preventing blood from reaching that area of the brain. Without blood, brain cells die. The symptoms of stroke depend on what area of the brain is affected. If blood is cut off to the motor cortex, one side of the body could be paralyzed. If the blockage is in the temporal lobe, near the speech center, the person may be unable to talk. Strokes can range from so mild that it is barely noticeable, to so severe that it causes death. Fortunately, the brain has great powers of recuperation, and can re-route neuronal networks around damaged areas. Given time, and lots of strengthening exercises, stroke patients can make substantial recovery. Doctors give stroke patients medicines that break up blood clots and prevent more from forming. (Your chances of having a stroke can be greatly reduced if you eat a low-sugar diet, exercise regularly, and don't smoke.)

Neurons are the only cells in the brain that do not reproduce. The other cells are constantly making copies of themselves so that when the original cells die there are new ones to take their place. Usually, cells reproduce at a slow, steady rate. Very rarely, one of the cells will get out of control and start reproducing so fast that a huge clump is formed. These fasting-growing cells don't know when to stop, and the clump gets bigger and bigger. The scientific name for this fast-growing clump of cells is a ***tumor***. When a tumor occurs in the brain, it is most often one of the glial cells that has gone bad. Tumors originating from neurons are not impossible but are very rare. Tumors are much more likely to start in any of the glial cells, or in the cells of the meninges or the blood vessels.

Some tumors will stay to themselves and not infect any other body parts. These tumors are called ***benign*** *(bee-NINE)*. Other tumors will send some of their cells to other parts of the body where they will teach those body parts to begin doing the same thing—growing and reproducing too fast. This type of tumor is called ***malignant*** *(mal-LIG-nant)*. In either case, the doctor may try to remove the tumor with surgery. In addition, the doctor may use medicine or radiation to kill off any remaining out-of-control cells. MRI scans are very helpful to doctors when they are diagnosing and treating tumors of the brain.

Some brain problems fall into the category of ***mental illness***. These are physical problems that are often made worse by situational or environmental factors. The symptoms often affect behavior, especially social behavior, but can include non-brain symptoms, also. One of the most common problems is ***depression***. Someone with depression doesn't just feel sad, their whole body feels bad. They may feel so tired that they can't get out of bed. They could have body aches or headaches, and they might stop eating (or eat to much). The treatments most often used are medicines that increase the amount of neurotransmitter chemicals in the synapses. The opposite problem is called ***mania***. The signals in the brain flow so fast that the person has too much energy and too many thoughts. They may talk non-stop, hardly sleep, and feel so energetic that they think they can do almost anything, even very unrealistic things. In a condition called ***bi-polar***, the person has both depression and mania, alternating back and forth. Medicines used for epilepsy are sometimes used to treat mania and bipolar disorder. They stabilize the brain and keep the activity from going too low or too high. Recent research has suggested that both depression and mania could be related to the activity of mitochondria in brain cells.

Schizophrenia *(SKITS-oh-FREEN-ee-ah)* is a mental illnesses characterized by the inability to tell the difference between reality and imagination. Schizophrenics often see and hear things that aren't real (hallucinations) or think they have magical powers such as mind reading or talking to spiritual beings. They usually have trouble with sleeping, organizing, and concentrating, as well. No one knows for sure what causes this illness, but genetics seem to be part of it. It is treated with medicines called "anti-psychotics" *(sie-KOT-iks)*. Some of these medicines aim to reduce the amount of a neurotransmitter called dopamine.

The most famous person who suffered from schizophrenia was the artist Vincent Van Gogh. (His painting "Starry Night" is shown here.)

Cerebral palsy is something you have from birth. It's not a mental illness. It is caused by damage to the cerebrum before, during, or right after birth. The word "palsy" means that the muscles don't function properly as a result of the brain damage. A person with cerebral palsy may walk awkwardly or have trouble speaking clearly. In severe cases, the person may be confined to a wheelchair, or be unable to dress or feed themselves. Sometimes they can experience seizures that cause muscles groups to contract repeatedly. Rarely, the palsy affects the frontal lobe and causes mental retardation, but in most cases the frontal lobe is completely normal. A person with cerebral palsy can be extremely intelligent, despite their difficulty walking and talking. Many people with cerebral palsy have jobs and careers and families, just like everyone else.

Another problem that can occur at birth, or shortly after, is ***hydrocephalus*** *(HI-dro-SEF-el-us)*. "Hydro" means "water" and "cephalus" means "head," so these babies have too much water (fluid) inside the head. You'll remember than the ventricles (empty spaces) deep inside the head are filled with cerebrospinal fluid. The ventricles are supposed to drain down through the spine, and out the bottom. If the "drain pipe" becomes blocked, the cells in the ventricles go right on producing fluid, and all that extra fluid has no place to go. The ventricles start to swell because of the extra fluid. The enlarged ventricles push on the brain and make the whole head expand. Needless to say, this is not good. Doctors must clear the blockage and get the ventricles to drain properly. Sometimes they put in an artificial drain pipe called a ***shunt***. They can leave this drain pipe in for a long time, even years, to make sure the ventricles don't get clogged again.

If something goes wrong with the blood-brain-barrier, and a bacteria or virus does get into the brain, it can cause a condition known as ***encephalitis*** *(en-SEFF-el-ITE-is)*. When you see "-itis" on the end of a word it means "inflammation." Encephalitis is inflammation (swelling) due to an infection inside the head. This causes fever and headache, usually accompanied by mental confusion. For example, the person might try to pick up objects that are not really there, or they may say things that don't make sense. Hospitals can treat encephalitis with special antibiotics that can get through the blood-brain-barrier. Fortunately, encephalitis is very rare, and certainly isn't something you need to worry about next time you get a fever with a headache. Many normal viruses also cause fever and headache, and the odds are good that you'll have one of these, not encephalitis.

Some brain problems occur as a result of getting older. Age-related diseases that cause problems with thinking and remembering are known as ***dementia*** *(de-MEN-shah)*. One type of dementia that is in the news a lot is ***Alzheimer's disease***. In Alzheimer's disease, neurons begin dying. Since you can't replace them, this means that those neurons are gone for good. The empty space where they used to be is filled in with cerebrospinal fluid. You wouldn't notice if even a thousand neurons died, but if millions start dying, you lose neuronal networks that you spent a lifetime building up. Memories and knowledge disappear. People with Alzheimer's generally get worse as time goes on, but there are new medicines being developed that can slow down the progress of the disease. Researchers are also looking into ways that the disease can be prevented, possibly with diet and exercise, or by taking small amounts of medicine that protects the neurons from damage. Alzheimer's research is becoming a very important branch of medical science and a lot of progress has been made in understanding how the disease works and what can be done about it.

Sometimes, age-related diseases turn out to have an infectious component to them. Researchers studying Lyme Disease examined the brains of people who (supposedly) died of Alzheimer's, and they discovered the bacteria that causes Lyme in many of the brains. Was this a coincidence? More research is needed.

A very common disorder that you may already be familiar with is ***Autistic Spectrum Disorder.*** This term, ASD, is a fairly new category that attempts to cover a broad range of related conditions, some mild and some severe. The word root "auto" means "self," so autistic disorders might have some overlap with narcissistic personality disorder, but to a psychiatrist or psychologist, they are distinctly different disorders. People with ASD lack the ability to see the world through someone else's eyes, but they are generally not manipulative. In fact, they are often quite innocent and they rarely commit crimes. People with any type of autism have trouble "reading" faces, so they often miss social cues that their normal friends pick up. For example, they can't tell if the person they are talking to is really interested in what they are saying. They have to be taught what to look for in facial expressions and body language.

In severe cases, autistic children can't even talk. They don't laugh or smile like other children, and spend much of their time doing repetitive actions that they find soothing. Most people with severe cases get better over time (with therapy), but some remain very disabled. Even people with disabling autism, however, sometimes have amazing abilities in one specific area (like the savant syndrome from chapter 3).

A mild form of autism is called ***Asperger's Syndrome***. The mildest cases often go undiagnosed and although society may see these people as a bit strange, they somehow find a niche for themselves and manage to live a fairly normal life, especially if they happen to have talents that people value.

The most common brain problems are on the very edges of the mental illness category, but tend to be treated as a separate category: ADD and ADHD.

ADD stands for **A**ttention **D**eficit **D**isorder. People with this disorder have a hard time concentrating or staying "on task." A student with ADD might not be able to pay attention in class. They might daydream when they are supposed to be completing an assignment. They are often forgetful and are constantly losing important items such as their keys, their phone, their wallet, their coat, etc. Sometimes treatment involves using medications, but many people simply decide to find ways to alter their behavior in order to minimize the impact of ADD.

ADHD stands for **A**ttention **D**eficit **H**yperactivity **D**isorder. People with this disorder have some of the same issues as people with ADD, but in addition they also have a jittery brain that takes their thoughts off in too many directions, making it hard not only to concentrate, but often even to sit still. Children with this disorder can be very disruptive in a classroom. Even with normal intelligence, they can have trouble learning. ADHD is believed to occur in the prefontal cortex area, due to a reduced supply of the neurotransmitters dopamine and norepinephrine. Treatment usually involves taking medications, one of the most common being Ritalin, which prevents the recycling of these neurotransmitters so that there is a higher concentration of them in the synapses.

Personality disorders also lie on the edge of the category of mental illness. Some are severe enough that they do merit being called a mental illness. Others are mild, and the person might go through their whole life without ever being diagnosed. Personality disorders are thought to be caused by a combination of genetics and environment. You are born with various tendencies, both strengths and weaknesses. Life circumstances will then shape you, causing certain traits to become more or less dominant. Sadly, abuse during childhood is all too often a major factor that contributes to developing a personality disorder. Personality disorders are the most difficult mental problems for doctors (and for society) to deal with because the person usually either does not know anything is wrong, or is unwilling to accept treatment. People who commit randoms acts of violence on total strangers (school shootings, etc.) almost certainly suffer from one of these syndromes.

"*Cluster A*" personality disorders include ***paranoia*** and ***schizoid*** disorder. People with paranoia develop irrational fears that everyone is "out to get them." They distrust everyone. In the worst cases, they become hostile to people because of these unfounded and irrational fears. Schizoid people have some of the same traits as schizophrenics, but develop less severe symptoms. They lack social skills and tend to be loners. They often appear "cold," having little or no emotion. They usually dress oddly and may say inappropriate things during conversations.

"Cluster B" personality disorders include ***antisocial, borderline, and narcissistic*** (nar-si-SISS-tick). People with **antisocial personality disorder** are aggressive, defiant, argumentative, angry, and compulsive (no self restraint). They are likely to break laws and commit crimes. When caught, they show no remorse for their actions.

Borderline personality disorder is harder to define. The word "borderline" refers to the fact that this The main characteristic of this disorder is instability. Borderlines often have sudden mood swings. For example, within minutes they can become so enraged that they say and do things that damage relationships. They are often very fearful, as well, and can be afraid of being alone. They might say or do anything to manipulate someone into not leaving. They are often impulsive and engage in risky behaviors. They often have low self-esteem and are prone to developing addictions. This disorder used to be seen as untreatable, but that is not true anymore. Many people have made great improvements through treatments offer by both psychiatrists and psychologists.

Narcissistic personality disorder is selfishness to the extreme. (Narcissus was a mythological Greek figure who fell in love with his reflection in a pool and spent the rest of his life staring at it.) We all struggle with a normal amount of selfishness. As babies and toddlers we thought the world revolved around us. We had to be taught how to share our toys. We may have been taught the Golden Rule, "Treat others as you, yourself, want to be treated." A normal brain has the capacity to learn these things. There appears to be a part of our brain that allows us to imagine how things look from another person's perspective. We call this "empathy." People with NPD can't do this; they seem to have no ability to empathize. Even as adults, they are unable to put the needs of others ahead of their own needs. If they seem to show humility, it is just an act in order to manipulate others in to doing their bidding. Rarely, people with NPD can overcome their disorder, but most often they go untreated because they think it's everyone else who has a problem, not them.

Some people with antisocial personality disorders can be classified as being either a "**sociopath**" *(SO-see-oh-path)* or a "**psychopath**"*(SIE-ko-path)*. Both disorders involve the person having no ability to understand how another person is feeling. PET and MRI scans of their brains reveal areas that don't look normal. As children, psychopaths are able to harm animals or younger children with no remorse. As adults, they learn to manipulate everyone around them in order to provide benefit to themselves. They don't care what the consequences are for other people. Sadly, some turn into killers whose crimes end up on the front page of newspapers. Sociopaths are the "light" version of the disorder and are less likely to commit crimes. Scientists estimate that 1% of the population has some type of narcissistic or sociopathic disorder.

"Cluster C" disorders involve intense anxiety and fear, and include "avoidant" disorder (extreme avoidance of things that are fearful), "dependent" disorder (extreme dependency when there doesn't seem to be any rational explanation for the dependency), and "obsessive-compulsive disorder" (OCD).

People with ***OCD*** have brains that concentrate too much, not too little. The brain concentrates so much on a few things that all other thoughts get pushed aside. This type of hyper-concentration is called "obsession." Commonly, people with OCD obsess about neatness, cleanliness or daily routines. For example, one woman straightened the mugs in her cupboard so all the handles pointed the same direction, but an hour later she was doing it again, then again a few hours after that. Her brain was in a continuous loop, never being able to accept the fact that this chore had been completed. People with OCD are often afraid of germs and will wash their hands so many times each day that their skin will be red and painful. Treatment for OCD usually combines medications with behavioral therapy.

ACTIVITY 10.3 Make the diagnosis

The doctor's in... and it's you! For each of the following patients, give your opinion of what might be wrong with them, based on what you read in this chapter.

PATIENT #1: Age 72. Often gets in the car, then forgets where he was going. Has been seeing staring blankly at items on his desk, not knowing what to do with them. MRI scans show large ventricles, which could be places where dead brain cells used to be.

A possible diagnosis: _____

PATIENT #2: Age 1 year. This baby had a difficult birth. She is having trouble learning to walk and seems unable to control her legs. She seems to have normal intelligence, just trouble with motor skills.

A possible diagnosis: _____

PATIENT #3: Age 10. Several times a day the patient stops what she is doing, moves around in a funny way for a few seconds, then seems fine again. An EEG machine recorded some unusual electrical activity.

A possible diagnosis: _____

PATIENT #4: Age 65. Experienced sudden loss of control over one arm. One minute he was fine, the next minute he could not move his arm. An EEG machine recorded normal brain activity.

A possible diagnosis: _____

PATIENT #5: Age 34. Complains of fatigue, loss of appetite, and feelings of despair. All blood tests have come back negative (meaning normal).

A possible diagnosis: _____

PATIENT #6: Age 6 months. Baby's head is too large on one side. MRI scans shows no tumors.

A possible diagnosis: _____

PATIENT #7: Age 24**.** Frequent headaches, but always on Friday or Saturday nights. Fine during the week. If asked to stretch her neck, the muscles seem very tight.

A possible diagnosis: _____

PATIENT #8: Age 12. The patient has had a mild headache for three days and is having trouble concentrating in school. The patient's mother says he was hit in the back of the head with a baseball three days ago.

A possible diagnosis: _____

ACTIVITY 10.4 Brain surgeries where the patient is awake—and playing music!

In some brain surgeries, the patient needs to be awake because the surgery is in a delicate area next to some motor nerves and the surgeon wants to make sure those motor nerves are not being damaged. (Remember, the brain itself doesn't feel any pain.) Depending on which part of the brain is being operated on, the surgeon may ask the patient to answer questions, move their arms or toes, etc. In rare cases, the patient is a professional musician and the surgeon wants to make sure their ability to play their instrument remains intact after the surgery. Because it looks so funny to see someone playing the banjo, guitar or violin while their brain is being operated on, these operations are often filmed, and some of these videos get posted on YouTube or other video streaming services. Start with these key words: "playing banjo during brain surgery." This will probably return a video (of famous banjo player Eddie Adcock) that doesn't actually show the brain, so there is nothing gross. If you like that one, you could try adding "guitar" or "violin" to key words "during brain surgery."

BIBLIOGRAPHY

These are the main books I used for my research (2007, 2014), listed in order of how much I used them:

The Brain and Central Nervous System, from the Reader's Digest series: *Your Body, Your Health*. Published in 2002 by Reader's Digest in Pleasantville, NY. ISBN 0-7621-0436-8

Big Head! by Dr. Pete Rowan. Published in 1998 by Alfred A. Knoff, NY. ISBN 0-679-89018-1

The Human Nervous System; An Anatomic Viewpoint, by Murray L. Barr. Published in 1979 by Harper & Row, Publishers. ISBN 0-06-140312-1

Inside the Brain, by Ronald Kotulak. Published in 1996 by Andrews McMeel Publishing, Kansas City. ISBN 0-8362-3289-5

How the Brain Learns, by David A. Sousa. Published in 2006 by Corwin Press, Thousand Oaks, California. ISBN 1-4129-3661-6

Mapping the Mind, by Rita Carter. Published in 1998 by University of California Press, Berkeley and Los Angeles. ISBN 0-520-22461-2

The Art of Changing the Brain, by James E. Zull. Published in 2002 by Stylus Publishing, Virginia. ISBN 1-57922-054-1

Right-Brained Children in a Left-Brained World, by Jeffrey Freed and Laurie Parsons. Published in 1997 by Fireside Books, a division of Simon & Schuster, NY. ISBN 0-684-84793-0

These are the main websites I used for the 2014 edition.
Also not listed are some YouTube videos I watched, although some of them are posted on the playlist.

Wisconsin Medical Society at www.wisconsinmedicalsociety.org

Howstuffworks.com

"Neuroscience for kids" at www.facutly.washington.edu/chudler/neurok.html

Wikipedia, the free online encyclopedia at: www. wikipedia.org

For the 2022 update, I checked facts using many Wikipedia articles, as well as using information from some of the videos that are posted on the Brain Curriculum playlist on YouTube.com/TheBasementWorkshop.

ANSWER KEY

ANSWER KEY

CHAPTER 1

ACTIVITY 1.1

1) CT 2) MRI 3) PET 4) MRI is dangerous for anyone with metal implants (because of the strong magnetism used) 5) PET, because it is the only one that can show activity level in real time.

CHAPTER 1.5

ACTIVITY 1.5

MRI:
1) Magnetic Resonance Imaging
2) Very large! The interior hole of an MRI is large enough for a person's entire body to go into it.
3) Yes, it has an incredibly powerful magnet inside.
4) Answers will vary. MRI is used to diagnose any problem that involves healthy versus unhealthy body tissue, such as tumors, joint deterioration, blockages, torn ligaments, heart disease, multiple sclerosis, and others. MRI can also be used in non-medical application such as determining the physical properties of rocks and other non-living materials.
5) Answers will vary. The strong magnet is used to line up protons in hydrogen atoms. Then, a radio frequency is pulsated in the area that is to be examined. The radio waves will cause some of the hydrogen atoms to absorb energy (causing "resonance"). When the radio waves are stopped, this extra energy is released, and is detected by the imaging system, which displays it on a screen.
6) fMRI can give 3D images and is used to detect changes in oxygen level in the tissues. fMRI studies metabolism and is more like PET in this regard. MRI only shows you structure, not functioning.

PET:
1) Positron Emission Tomography
2) Patients must receive an injection of radioactive glucose (sugar).
3) The PET scan is used to show the <u>level of activity</u> in bodily tissues (as opposed to MRI which shows structure, not activity). In other words, PET scans show how quickly cells are using glucose. Normal tissue and diseased tissue use glucose at different rates and this shows up on PET scans as different colors.
4) The PET scan detects radiation given off by the radioactive glucose. The more radiation, the brighter the color.
Cells that are more active will have more of the radioactive glucose in them, therefore they will appear as reds and yellows. Less active areas will be blues and greens.
5) PET is used to diagnose many heart conditions and blood flow problems. It can also be used to search for tumors, since they take up glucose at a faster rate than normal tissue.

CHAPTER 2

ACTIVITY 2.1

ACROSS: 3) corpus callosum, 5) capillaries, 7) frontal, 8) white, 9) sensory, 10) parietal, 11) stem, 14) temporal, 15) cortex, 16) blood
DOWN: 1) occipital, 2) cerebellum. 4) cerebrospinal fluid, 6) cerebrum, 12) motor, 13) gray
BONUS QUESTION: left

ACTIVITY 2.4

2) Playing the piano
FRONTAL LOBE: Decides to play, understands what you are playing, send signals to motor cortex to move fingers, interprets what the musical notation means ("reads" the music)
MOTOR CORTEX: Sends signals to fingers (and to feet if you are using pedals)
SENSORY CORTEX: Feels the keys under your fingers
PARIETAL LOBE: Senses where your hands are arms are in relationship to the piano, senses that you are sitting in front of the piano, helps keep you balanced on your piano bench
OCCIPITAL LOBE: Sees the notes on the sheet music
TEMPORAL LOBE: Hears the notes as they are being played

3) Riding a bicycle
FRONTAL LOBE: Decides to ride, knows where you are going and makes decisions about whether to turn left or right, sends signals to motor cortex,
MOTOR CORTEX: Sends signals to muscles in arms and legs
SENSORY CORTEX: Feels the wind on your skin, feels the pedals under your feet, feels the hand grips in your hands
PARIETAL LOBE: Helps you keep your balance on the bike
OCCIPITAL LOBE: Sees the landscape around you
TEMPORAL LOBE: Hears things like birds singing, traffic sounds, the wind in your ears

4) Talking on the phone
FRONTAL LOBE: Decides what to say and when to say it, sends signals to the motor cortex
MOTOR CORTEX: Sends signals to the muscles in the mouth and vocal chords (and your hand that is holding the phone)
SENSORY CORTEX: Feels the phone in your hand
PARIETAL LOBE: Isn't essential for talking on the phone, but it is doing its basic job of sensing where your body is in relationship to the objects around you
OCCIPITAL LOBE: Isn't essential for talking on the phone, but if your eyes are open, it is taking in the sights around you
TEMPORAL LOBE: Hears the words that are being said to you by the other person, makes sense of the words and sentences you are hearing.

CHAPTER 2.5

ACTIVITY 2.4

We measured the cortex on the left to be about 26 centimeters and the one on the right to be about 22 centimeters, but your measurements might be a little more or less. The main point is to notice how folding and creasing allows something to occupy a smaller area. If you straightened out those cortexes, they would extend well beyond the edges of the page!

ACTIVITY 2.8

1) DURA 2) PIA 3) ARACHNOID 4) FISSURE 5) CORPUS 6) CALLOSUM
7) ANTI 8) CEREBRUM 9) CEREBELLUM 10) GYRUS 11) SULCUS
12) OCCIPITAL 13) CORTEX 14) MENINGES 15) PARIETAL

CHAPTER 3

ACTIVITY 3.3

Pennsylvania, Minneapolis, Arkansas
San Diego, California, Tennessee

ACTIVITY 3.6

The one turned the wrong way is C.

CHAPTER 4

ACTIVITY 4.2

ACROSS: 3) motor cortex 7) fornix 8) parietal 11) occipital 13) hypothalamus 14) pituitary 16) midbrain
17) temporal 18) sensory cortex
DOWN: 1) cingulate gyrus 2) amygdala 4) cerebellum 5) medulla oblongata 6) olfactory bulb 7) frontal
9) hippocampus 10) pons 12) ventricles 15) thalamus

CHAPTER 5.5

ACTIVITY 5.6

1) fissure 2) gyrus 3) sulcus 4) ventricles 5) homunculus 6) dendrites 7) Schwann cell 8) node of Ranvier 9) nucleus
10) glial cell 11) pons 12) medulla oblongata 13) cerebellum 14) occipital lobe 15) parietal lobe 16) sensory cortex
17) motor cortex 18) frontal lobe 19) olfactory bulb 20) cingulate gyrus 21) corpus callosum 22) midbrain 23) thalamus
24) skull 25) dura mater 26) arachnoid layer 27) pia mater 28) cortex (gray matter) 29) PET scan 30) MRI scan
31) synapse 32) neurotransmitters 33) receptor site 34) vesicles 35) axon knob

ACTIVITY 5.6

NOTE: If you came up with a different answer but it makes sense, you can count that, too.
1) "limbic" because the other three are lobes of the cerebrum and the limbic system is not.
2) "synapse" because the other three are words that describe shapes found on the cerebrum and a synapse is a microscopic gap, not a shape.
3) "CRV" is not a type of brain scan.
4) "neuron" because it is not a glial cell.
5) "carbon dioxide" because it is a waste product and the other three are things the brain needs.
6) "Gage" because the other three are scientists. Gage was not a scientist.
7) "medulla oblongata" because it does not play a role in memory.
8) "frontal lobe" because all the others are connected to the senses in some way. The frontal lobe is not directly connected to any senses.
9) "pituitary gland" because there is just one of them, and the other structures all have two sides or two lobes
10) "synapse" because it is not actually part of a neuron. It is nothing but empty space!
11) "homeostasis" because it is not a word associated with the synapse
12) "potassium" because it is not something that directly affects neurotransmitters

ACTIVITY 5.7

1) False, it is in the temporal lobe. 2) True 3) True 4) False, Schwann cells are found only in the body, not in the brain. Oligodendrocytes perform the insulation function in the brain. 5) True 6) False, a shunt carries cerebrospinal fluid away, not blood. 7) True 8) False, this is why alcohol can make you intoxicated. 9) True, because more wrinkles means more surface area, which means more cortex which means more area for brain functions. 10) True 11) True, because the BBB is created by tight junctions between cells. 12) False, the neurotransmitters are made inside the neuron. 13) True 14) False, there are four ventricles. Two are matching left and right, two are 15) True

CHAPTER 6

ACTIVITY 6.2

1- 6) frontal, motor cortex, sensory cortex, parietal, occipital, temporal
7) beating of heart, keeping lungs breathing
8) Helps with balance, coordinates movements 9) sea horse 10) the basal ganglia
11) pons 12) occipital 13) temporal lobe 14) motor cortex 15) frontal
16) temporal 17) hypothalamus 18) nose 19) grow 20) dendrites
21) L 22) R 23) R 24) R 25) L

Check your answers with the diagram on page 23

CHAPTER 6.5

ACTIVITY 6.4

First joke:

Node of Ranvier, oligodendrocytes, Schwann, neurotransmitters, knobs, myelin, receptor sites
PUNCH LINE: "Hey, kid, you've got a lot of potential!"

Second joke:

plasticity, billion, serotonin, network, hippocampus PUNCH LINE: the Neural Network

CHAPTER 7.5

ACTIVITY 7.6

IMPLICIT: how to tie my shoe, how to do a certain dance, how to type on the keyboard without looking, how to zip a zipper, how to sign my name
EPISODIC: the phone number of Carlo's Pizza (could possibly be semantic, if you have known it a long time), my math lesson from last week, how my yard looks in the winter (if it is winter right now and you are remember seeing it today or yesterday), where the Hawaiian Islands are located (if you just learned this in the past few days or so), how my bedroom looks right now, don't mix peppermint with cola, I must be home by 9. my homework assignment for tomorrow, the dog next door bites (assuming you learned the hard way), what I got for my birthday
SEMANTIC: the feel of my dog's fur, 3x3=9, how my yard looks in the winter (if it is a general memory, not a recent memory from today or yesterday), where the Hawaiian Islands are located (assuming you have known it for a while), how to spell the word "brain," the nursery rhyme "Humpty Dumpty," the fact that birds can fly

ACTIVITY 7.8

1) CHUNKING 2) IMPLICIT 3) PROCEDURAL 4) EPISODIC 5) SEMANTIC
6) EXPLICIT 7) SEVEN
Answer to question: Mental exercise and nutrition

CHAPTER 8

ACTIVITY 8.1

C	F	M	Y	H	L	T	H	B	L	Y	M
E	Z	E	E	N	S	W	C	L	R	A	R
N	D	O	R	L	N	V	T	I	R	W	O
B	X	G	A	G	P	S	A	R	G	N	P
I	L	S	H	J	L	S	R	M	F	T	F
J	T	I	M	O	V	I	C	O	U	G	H
O	R	W	N	C	U	D	S	A	L	R	H
M	F	S	L	K	H	O	Z	N	G	D	L
E	S	P	A	T	E	L	L	A	R	E	Y

ACTIVITY 8.4

1) T 2) T 3) F 4) F 5) T 6) T 7) T 8) T 9) T 10) T

CHAPTER 8.5

ACTIVITY 8.8

1) auditory 2) cervical 3) eye 4) light, deep 5) optic 6) nose 7) cochlea 8) thoracic
9) atlas 10) synesthesia 11) lumbar 12) pain 13) temporal 14) cones 15) temporal

CHAPTER 9.5

ACTIVITY 9.6

1) frontal, motor, sensory, parietal, occipital, temporal 2) keeps your heart and lungs going
3) waking /sleeping cycle, wakes you up 4) hypothalamus 5) glial 6) cervical 7) lumbar 8) optic 9) auditory
10) peripheral 11) central 12) involuntary 13) meninges 14) rapid eye movement 15) melatonin 16) beta, alpha
17) delta 18) five 19) 4 20) Samuel Taylor Coleridge

CHAPTER 10

ACTIVITY 10.2

1) K 2) E 3) S 4) J 5) M 6) T 7) A 8) X 9) Y 10) U 11) O 12) R 13) N 14) V 15) L 16) F
17) Q 18) W 19) D 20) P 21) H 22) I 23) Z 24) B 25) C 26) G

CHAPTER 10.5

ACTIVITY 10.3

Please note that this activity is only meant to be a fun way to review reading material from the chapter. It is not meant to be an actual diagnostic activity!
Patient #1: Alzheimer's
Patient #2: cerebral palsy
Patient #3: epilepsy
Patient #4: stroke
Patient #5: depression
Patient #6: hydrocephalus
Patient #7: tension headaches
Patient #8: concussion

TEACHER'S SECTION

Additional resources and in-class activities

All patterns in this section are reproducible and may be photocopied for student use.

For those who are working from a paperback copy and would like to have digital patterns to use for printing at home, go to: www.ellenjmchenry.com/brain

ADDITIONAL ACTIVITY IDEAS

CHAPTER 1

Activity idea 1A: Do an "MRI" of an orange

You will need:

- several oranges (the big, not-too-juicy kind is best)
- a sharp paring knife
- a cutting board
- something square on which to lay out all the slices (paper towels are fine)
- a pointed wooden skewer or a large nail
- a small syringe or eye dropper
- food coloring
- optional: raisin or something else firm and soft, to implant inside the orange

You will need to prepare the orange ahead of time by either inserting a few drops of food coloring with an eye dropper or small syringe, or else poking a hole and inserting a raisin or piece of cheese or other soft item that will slice easily when you are slicing the orange. (You can pre-poke a hole with a skewer or nail before inserting the dropper or syringe.)

First, show the students an MRI or CT image so that they can see that these scans are often not just one image, but a whole series of images. Explain that each image represents a very thin "slice" of the head. The first image is the top layer, and the last image is the bottom one, with the rest of the images exactly in order from top to bottom.

Explain that you will simulate an MRI by using an orange for a head and actual slices instead of scanner images. (Make sure the students understand that real MRI's don't really slice your head!) Before you begin slicing, you may want to draw a line down one side with a permanent marker. If the orange was a real head, this line would go between the eyes and through the middle of the nose and mouth. This line will help you keep the slices oriented correctly when you lay them down. Then begin slicing the orange and lay out the slices in order as they are cut. Make the slices as thin as possible. You'll end up with about 12-15 slices.

MRI and CT scans look like a series of slices.

Slices of an orange that had some blue food coloring injected with an eyedropper. It leaked to the side more than planned, but even so, the color was not very visible from the outside. (This orange doesn't have a raisin implanted.)

CHAPTER 2

Activity idea 2A: Take a "hands-on" tour of the cerebrum (especially helpful for younger students)

The teacher or parent leads this activity, demonstrating where the students are to put their hands while they listen to the teacher/parent tell them the information about each lobe.

FRONTAL LOBE: *Make one hand cover the whole forehead*. Underneath your hand is your frontal lobe. If you see someone in this position it looks like they are thinking, or like they forgot something. This is how you can remember that the frontal lobe is where your thinking and deciding takes place. This is the lobe that is in charge. It's got a lot of responsibility! Isn't it funny that when this lobe gets stressed, we put our hand on it?

MOTOR CORTEX: *Put each hand into a fist except for the first (pointer) finger sticking up. Then touch the tips of the fingers together, like they are pointing at each other. Keeping them together, put them on top of your head so they form a band right over the top (a little like a hair band).* The strip of brain underneath your fingers is called the motor cortex. The word "motor" makes you think of movement. The motor cortex is the place in the brain that sends the signals to your muscles telling them to move. Notice that it is right next to the frontal lobe. This is handy, because the frontal lobe is what tells the motor cortex to send out its signals. Your frontal lobe decides the body needs to move, then the motor cortex actually sends out the signals.

SENSORY CORTEX: *Move your finger "hair band" back about one centimeter (half an inch)*. The thin strip of brain running underneath the place where your fingers are is called the sensory cortex. *Make those two fingers rub or scratch your head.* This is a clue as to what the sensory cortex does. The sensory cortex is where your brain processes the "touch" sensations coming in from all parts of your body. When something scratches or touches your skin, the signals are sent to the sensory cortex.

PARIETAL LOBE: *Take one hand and put it over the crown of your head, right over the place where your hair sprouts out.* Underneath your hand is your parietal lobe. The name of this lobe comes from the Latin word for wall. That doesn't make much sense, does it? Actually, the lobe is named after the part of the skull that covers it, the parietal bone. The parietal lobe is not very well understood, and remains somewhat of a mystery, but we do know the parietal lobe helps you to know where your body parts are, even if you can't see them. Try this: Put your arms out to the sides, close your eyes, and stick out your index (pointer) fingers. Can you bring your index fingers together without opening your eyes? You probably can, or very nearly so. How can you know where those fingers are without looking at them? It is your parietal lobe that keeps track of where they are. The parietal lobe also works with your cerebellum and inner ear to give you your sense of balance. It also play a role in understanding shapes in geometry and abstract ideas of mathematics (what Einstein was good at!).

OCCIPITAL LOBE: *Put your hands behind your head, with fingers "knitted" together, as though you are lying in a grassy field watching the clouds roll by*. Behind your hands is your occipital *(ok-SIP-it-al)* lobe. This is the lobe where your vision is located. It's what actually "sees" those clouds floating by. The images from your eyes are sent to the occipital lobe for processing. When the images come in, they are upside down and your brain must learn to turn them right-side up. A brain researcher once tried an experiment where he asked someone to wear special glasses that made everything look upside down. The result was that the occipital lobe compensated for what the glasses were doing and reversed the image a second time, making everything appear right-side up again!

TEMPORAL LOBE: *Put your fingers on your temples.* Behind your fingers and over your ears is the temporal lobe. This part of the brain is connected to your ears, which is not surprising, but is also where your sense of smell is. In addition to these functions, the temporal lobe is where your speech center is located. Right behind your temple is the area that forms words and sentences (then relays this to the motor cortex, which makes your lips and tongue move). Right above your ear is the area that understands words and sentences.

Activity idea 2B: Brain cookies

You will need a batch of standard sugar cookie dough and some food coloring. (You are welcome to adapt as needed: sugar-free, gluten-free, natural dyes, etc.) Divide the dough into at least four parts. Use food coloring to color each a different color. (The more colors the better.) Use the outline drawing shown in activity #2.3 in chapter 2 as your guide to make a flat cookie where each lobe is a different color.

Activity idea 2C: Draw brain parts on a real head

You will need a tight-fitting swim cap and a marker. Put the cap on a volunteer, then draw in the lobes on the cap. (This activity is guaranteed to produce smiles and laughs.)

Activity 2D: Cerebrospinal fluid experiment

You will need:

- at least two raw eggs
- at least one small plastic container just slightly larger than the egg (Two identical containers is best, as it will save you clean up time in the middle of the experiment and let you do it at the end.)
  NOTE: Small clear plastic jars with screw lids (used for peanut butter in America) are ideal
- water
- rubber bands or duct tape (or both) to keep the lid on the container if not using screw lids
- a large pot into which you can drop the container (to avoid getting raw egg on floor)
- on hand: paper towels for clean up

Put a raw egg inside the container. The egg will represent the brain and the container will represent the skull. This part of the experiment simulates what would happen if your brain had no fluid around it. Secure the lid by either screwing it on tightly, or using rubber bands or duct tape. Shake the container. If the egg survives the shaking, drop the container into the large pot. If it survives, drop it again from a greater height. At some point, the egg will crack.

Empty the container (or use the other one). Put in a fresh egg and then fill the container with water and secure the lid.tightly. Shake and drop the container again, and see what happens. Does the water around the egg protect it from breaking?

NOTE: Some plastic containers will be more brittle than they appear and will crack when dropped. Use either soft plastic containers, such as a yogurt containers. or an extremely heavy-duty container such as the indestructible “Tupperware” type.

Activity idea 2E: Observe a thin membrane similar to the meninges in the brain

You will need:

- a raw egg
- something to crack it into
- paper towels

Crack the egg and dump out the contents. Carefully crush the side of one of the empty egg shells, so that you have some pieces that are being held together by a thin membrane. Notice that the membrane is attached to the inside of the egg shell. In the brain, the outer layer of the meninges (the dura mater) is attached to the skull. Now gently pull the cracked pieces away from the rest of the shell so that the membrane slowly peels off the inside of the shell. It's not too hard to do. You should be able to get a piece of membrane at least a centimeter wide and two centimeters long, possibly larger. (If it doesn't seem to be working, try a different egg.) Gently pull and stretch the membrane to test its strength. It's surprisingly tough. You might want to see what happens if you leave the membrane out to dry. How does lack of water affect its strength?

OPTION: Use a hard boiled egg to make the experiment less messy.

Activity 2F: Compare the human brain to animal brains

If you log on to the website **www.brainmuseum.org**, you will find a library of images of animal brains. On the menu bar on the left, click on LIST OF SPECIMENS. Then click the names of animals to see their brains. Notice differences in the sizes of the cerebrums, and in the amount of wrinkles. Remember that the reason a brain has wrinkles is to get a large surface area into a small space. If a brain does not have wrinkles, this indicates that it has a smaller surface area. Less surface area means less mental capability. Compare the rabbit brain with the bat brain. Which animal is probably more intelligent? Compare the manatee with the dolphin. Can you find any differences between a chimpanzee brain and a human brain?

CHAPTER 3

Activity idea 3A: Play "charades"

A great left brain/right brain game is "charades." The players giving the clues are using the right side of the brain. The players trying to guess the correct word are using language skills on the left side of the brain. You can play the standard way with hand gestures and motions used as clues, or you can get even more right-brained and make the clue givers sculpt their clues out of modeling dough or draw the clues on a paper or white board.

Activity idea 3B: Do more drawing using the right hemisphere

For more activities and information about drawing with the right side of the brain, use the first four chapters of the book Drawing on the Right Side of the Brain by Betty Edwards. You will find many easy and interesting drawing activities that require little or no preparation on the part of the teacher. Everything you need or need to know is in the text. The book works best with middle or high school students.

Activity idea 3C: Make up your own rebus puzzles

You might want to start by searching the Internet for "rebus puzzle" so the students can get a better feel for what they are. Then ask them to make up a few of their own. Making rebus puzzles uses different brain parts than solving them.

Activity 3D: Make a "hemisphere hat"

NOTE: If you working from a paperback version of this book instead of a digital copy, you can get digital patterns by going to to www.ellenjmchenry.com/Brain. Or, go to my website and click on FREE DOWNLOADS then on HUMAN BODY, then on the "brain hemisphere hat." (The hat even comes in other languages!)

You will need:

- copies of the patterns printed onto white card stock
  NOTE: Most home printers can print on regular weight card stock. Don't use super heavy "cover stock." Print shops can print on heavy cover stock.
- scissors and clear tape
- optional: good white glue (see note below)

NOTE: If you use white glue, I recommend using clothespins or paper clips to hold the joints while they dry. Also, for those of you living in North America, please note that for us, white glue (such as Elmer's) isn't what it used to be. "School glue" is just about useless for paper crafts. In the UK, "PVC glue" is still good. (I order them from amazon.co.uk.) A good white glue will hold if you apply just a tiny dab, then press the joint and count to ten. If you don't want to special order PVC glue, try Aleen's Tacky glue, or a high quality craft glue intended for adult use. If you want to try a glue stick, make sure to buy the "extra strong" kind intended for adults.

You can tape all the joints with clear tape if you don't mind seeing the tape on your final product. Kids don't seem to care about it and are usually fine with tape. Even if you use glue for the V-shaped seams, use tape on the inside of the hat when you do the seam down the middle, joining the two halves.

ABOUT THE PATTERNS:

There are both color and black and white, and labeled and unlabeled patterns to give you maximum flexibility. You can add color to the gray hats. Color lightly, though, so you don't obscure the words. Do all coloring before you assemble them.

The hat is designed to be as "one-size-fits-all" as possible, although the color pattern does come in LARGE and SMALL. The smaller size is for use with children under the age of 10, though head sizes can vary more with body type than with age. With either pattern, the size of the hat can be made a little smaller by overlapping the two hemispheres a little more before taping them together. If necessary, the folds can also be overlapped a bit, as well.

If you are doing this project with a class, you might want to have pre-assembled hats in both sizes for the students to try on before assembling their own.

Cut out both hemispheres, cutting around the outside edge. Then snip in on the solid V line. Don't snip on the dashed lines! Then pull the "flap" you have created over to the dashed line and secure with glue or tape. After you have pulled all the flaps over to their dashed lines, it should then take on a half-round shape.

To put these two halves together, simply choose one side to overlap just slightly onto the other (but overlap more if you are trying to shrink the size of the hat) and secure with tape. Use the same approach that you would for sewing a curved seam. Working on the inside of the hat, start on one end and secure just that end with tape. Don't worry if the rest of the seam is wide open. Then pull the hat together correctly just at the end inch or so. Tape that in place. Then do the next little bit, not worrying that the rest of the seam is still gaping open. Just work you way down the seam little by little. When you read the end, the hat should have a nice shape.

Optional cerebellum: If you want to add the cerebellum just fasten it to the inside of the back of the hat as shown in photo. Glue or tape in place.

If you need more thorough instructions, there are assembly photos included with the pattern download on the website.

RIGHT SIDE

LARGE

1) Cut around the outside edge.
2) Cut on the solid lines (the ones the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape in place.

OPTIONAL:
(not required)
Add a cerebellum if you want to.
1) Cut out CEREBELLUM.
2) Tape onto the inside of the hat, as shown.

LARGE LEFT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the line that the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape inplace.

OPTIONAL:
(not required)
Add a cerebellum if you want to.
1) Cut out CEREBELLUM.
2) Tape onto the inside of the hat, as shown.

SMALL
RIGHT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the ones the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape in place.

OPTIONAL:
(not required)
Add a cerebellum if you want to.
1) Cut out CEREBELLUM.
2) Tape onto the inside of the hat, as shown.

SMALL
LEFT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the line that the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape inplace.

OPTIONAL:
(not required)
Add a cerebellum if you want to.
1) Cut out CEREBELLUM.
2) Tape onto the inside of the hat, as shown.

LEFT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the line that the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape inplace.

RIGHT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the ones the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape in place.

LEFT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the line that the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape inplace.

RIGHT SIDE

1) Cut around the outside edge.
2) Cut on the solid lines (the ones the arrows are pointing to).
3) Tuck the flaps under until the dashed line meets the solid line, and glue or tape in place.

CHAPTER 4

Activity idea 4A: Dissect a sheep brain

If you would like your students to get up-close and personal with a real brain, you can get a sheep brain for about $10, plus shipping, from Home Science Tools. The item number is PM-BRAINSH. If you would like a dissection guide to go with it, you can get one for about $1.50, item number DE-GDBRAIN. You can order online at www.homesciencetools.com, or phone 1-800-860-6272. The address is 665 Carbon St., Billings, MT 59102. Note: This is one of the few places that individuals can get preserved specimens. Most science supply stores require documentation proving that you are a school.

Activity idea 4B: Play the "-Ectomy" Game

When surgeons do any kind of "-ectomy" that means they take something out of the body. An appendectomy is when you have your appendix removed. A tonsillectomy is when you have your tonsils out. In this game, you might have a lobe of your brain removed. But don't worry—you can win it back again by answering questions about the brain!

You will need:

- a copy of the "-Ectomy" board for each player (can be printed on different colors)
- a copy of the labeled brain parts page for each player (white, or same color for all, as they will be shared)
- one copy of the set of cards for each group of players that will be playing together.
- scissors

Card stock is recommended for the cards and brain parts. Regular paper is okay for playing boards. If you want the brain parts to survive multiple uses, you can also print them onto sticky back paper and stick them to craft foam.
FOR DIGITAL PATTERNS YOU CAN USE TO PRINT AT HOME: www.ellenjmchenry.com/Brain

Cut apart the playing cards, shuffle them and put them face down in a pile. Cut apart the sections of the labeled brains into eight separate lobes. Be careful to cut right on the lines so that the pieces will be as interchangeable as possible. (To make the pieces extra durable, you could laminate them, or adhere them to the sticky side of sticky-back craft foam sheets.) Put everyone's brain lobes into a communal pile. Each player should have their own empty brain board in front of them.

The first player draws a card without looking at it, and gives it to the player on his left, who then reads the question to the first player. (Don't read the answer, which is printed in capitals.) If the first player gives the correct answer, he earns that brain part. He selects that part from the pile and puts it where it belongs on his own board. The quiz card is then returned to the bottom of the pile. If a player draws an "-Ectomy" card, he follows the directions on the card, then returns it to the bottom of the pile. If the player draws an "-Ectomy" card for a part he does not have, he simply returns the "-Ectomy" card to the bottom of the pile and takes the next top card.

If a player draws a card that offers a lobe he already has, he answers the question anyway. If he answers correctly, he has two options. The first option is to take the extra lobe and then trade with someone else who needs it and who happens to have a lobe that he needs. For instance, if player one wins an extra temporal lobe and already has one, but needs a frontal lobe, he looks to see if another player needs a temporal lobe and has a frontal lobe. Player two has a frontal lobe but no temporal lobe. Player one may take player two's frontal lobe but give him the temporal lobe he needs in return. The second option is to draw another card and answer another question. In this case, the player may draw up to three cards.

The first player to get all their brain parts wins.

-ECTOMY

PRINT ONE COPY FOR EACH STUDENT

You may receive any brain part if you can answer this question: About how much does a human brain weigh? 1.5 KG (3 POUNDS)	You may receive any brain part if you can answer this question: About how thick is the outer cortex of the cerebrum? 1/2 CM (1/4 INCH)	You may receive any brain part if you can answer this question: What kind of scan is in color and can show the brain working? PET
You may receive any brain part if you can choose the correct number: How many gallons of blood does the brain receive every hour, 1, 8, 28 or 80? (8)	You may receive any brain part if you can answer this question: What connects the right and left sides of the cerebrum? CORPUS CALLOSUM	You may receive any brain part if you can answer this question: What is the correct name for the brain's "gray matter"? (CEREBRAL) CORTEX
This lobe of the brain is between the sensory cortex and the occipital lobe. PARIETAL LOBE	This part of the brain is between the frontal lobe and the sensory cortex. MOTOR CORTEX	If you hit the back of your head and "see stars" this is the lobe that is affected. OCCIPITAL LOBE
This part of the brain is located right at the top of the spinal cord. MEDULLA	This is part of the brain stem and is located between the medulla and the cerebrum. PONS	You may collect any brain part if you can say which brain part produces the hormone "melatonin" which helps you sleep. PINEAL GLAND
This part of the brain can't function when your eyes are closed. OCCIPITAL LOBE	This part of your brain is right behind your forehead. FRONTAL LOBE	This lobe listens to music. TEMPORAL LOBE
This part of your brain could be called your "alarm clock." PONS	You may receive any brain part if you can answer this question: What is the correct name for one of the curving ridges on the surface of the brain? GYRUS	You may receive any brain part if you can answer this question: What is the main function of the hippocampus? MEMORY

PRINT ONE COPY FOR EACH GROUP OF PLAYERS

This part of your brain grows rapidly and almost reaches adult size by the age of two. CEREBELLUM	This part of your brain allows you to be graceful. It coordinates your movements. CEREBELLUM	This lobe is connected to your eyes. OCCIPITAL
This part of the brain receives information from the skin. SENSORY CORTEX	This lobe of your brain is where your speech center is located. TEMPORAL LOBE	This part of your brain can sense the texture of your dog's fur. SENSORY CORTEX
This part of the brain makes the decision to move and then sends signals to the motor cortex. FRONTAL LOBE	Collect any brain part if you know which part is right below the thalamus and controls hunger. HYPOTHALAMUS	This lobe thinks in three dimensions and keeps track of where your body is in space. PARIETAL LOBE
This part of your brain decides whether you will wear the red shirt or the blue shirt today. FRONTAL LOBE	This lobe is where your sense of smell is located. TEMPORAL LOBE	This part of your brain sends out electrical signals to move your muscles. MOTOR CORTEX
Your vomit reflex is located in this part of the brain. MEDULLA OBLONGATA	This brain part wakes you up in the morning. PONS	This part of your brain works with your inner ear to give you your sense of balance. CEREBELLUM
This brain part keeps your heart and lungs working while you sleep. MEDULLA OBLONGDATA	This is the lobe of your brain where you add and subtract numbers. FRONTAL LOBE	This name of this brain part means "little brain." CEREBELLUM

PRINT ONE COPY FOR EACH GROUP OF PLAYERS

You may receive any brain part if you can answer this question: What stops most chemicals from entering the brain? BLOOD-BRAIN-BARRIER	You may receive any brain part if you can answer this question: Which side of the brain is more creative and musical? RIGHT	You may receive any brain part if you can answer this question: Which side of the brain is more logical? LEFT
You may receive any brain part if you can answer this question: Which side of the brain uses words and symbols to name things? LEFT	You may receive any brain part if you can answer this question: Which side of the brain is good at drawing and sculpting? RIGHT	You may receive any brain part if you can answer this question: Which side of your brain controls the left side of your body? RIGHT
This lobe of your brain is right under the “crown” of your head, where your hair sprouts out from a central point. PARIETAL	This part of your brain allows you to know what your body parts are doing even when you have your eyes closed. PARIETAL	This part of your brain is where your coughing and sneezing reflexes are located. MEDULLA OBLONGATA
-ECTOMY Remove your parietal lobe	-ECTOMY Remove your cerebellum	-ECTOMY Remove your motor cortex
-ECTOMY Remove your frontal lobe	-ECTOMY Remove your temporal lobe	-ECTOMY Remove your occipital lobe
-ECTOMY Remove your medulla	-ECTOMY Remove your pons	-ECTOMY Remove your sensory cortex

PRINT ONE COPY FOR EACH GROUP OF PLAYERS

Activity idea 4C: A refrigerator magnet craft

Here's another way to review brain parts. This magnet puts brain anatomy in a place where the whole family will see it often—on the refrigerator!

<u>You will need</u>:

- Model Magic® sculpting dough in "bisque" or "terra cotta" color. One package of Model Magic® will be enough for 3-4 students, depending on how thickly the dough is applied. (The reason I use Model Magic® is because it is so incredibly light. A cheaper, but heavier dough will be too heavy for small magnets to hold up.)
- Model Magic® in red (but only if you have a group and it is worth purchasing a whole packet) You only need a very small amount of red, so don't go buying a whole packet for one or two students. You can always use a red Sharpie marker to color a little bit of your brain-color dough. Or maybe substitute red Play Doh.
- a piece of foamcore or corrugated cardboard (if you don't have either, use cereal box cardboard)
- a copy of the pattern page (following) printed onto card stock (Each student will only need one of the picture, one fourth of the page.)
- colored pencils
- adhesive-backed (peel and stick) "button" magnets (at least 1/2" diameter)
- at least one picture from the Internet (downloaded and printed unless you can view the screen while sculpting), that shows exterior of brain
- something that will press thin lines into the dough (such as a table knife that is not sharp, or a wooden coffee stir stick, or even the edge of an index card)

NOTE: If you can only get Model Magic® in white or brown, you can go ahead and use it and just paint it when dry. (NOTE: Model Magic® takes several days to dry. A week to be completely safe.) Use a peach-colored acrylic paint (sold in bottles for less than a dollar at any craft store or craft department). The paint dries quickly but can be hurried even more if you blow dry it with a hairdryer. With a hair-dryer it will dry in about 5 minutes. (The hair dryer trick won't work on the Model Magic®. It will still take a few days to dry.)

NOTE about pattern page: Two pattern pages are provided, one labeled, one unlabeled. You can choose which is best for your situation. Print on white card stock if possible.

(1)

(3)

(4)

(5)

(6)

(7)

(8)

(8)

(10)

(11)

(12)

Directions:

1) Cut out the paper pattern (following page). Put the pattern face down onto foamcore or corrugated cardboard and trace. (Brown cardboard shown here so the pattern can be seen, but I prefer white foamcore.)

2) If using foamcore, cut with X-Acto knife (adult job!). (I cut foamcore with my scroll saw.) If you don't have an sharp knife, a good pair of scissors might work. If using cardboard, can cut with scissors.

3) Color the pattern page (showing inside brain parts) with colored pencils or crayons. (If working in a group, have them write their name or initials somewhere on this diagram, in very small letters.)

4) Before gluing the pattern page onto the foamcore/cardboard, use it as a guideline to draw in roughly where the brain stem and cerebellum will go. You might also want to add a line for the temporal lobe.

5) Glue the pattern page to the back of the foamcore (cardboard) you just cut out.

6) Turn back to the blank side and begin your sculpting. Put in the brain stem first. (You can roll an oval for the pons if you want to.)

7) Put some dough on the cerebellum area. Use the table knife or craft stick to put texture lines into the cerebellum.

8) Roll long "snakes" to use for the cerebrum. Make the "snakes" a little smaller than a small child's finger. Form the temporal lobe area first,

9) then do the top of the cerebrum. Every person's brain is unique, so the students don't have to make theirs look just like the picture. They can make the squiggles however they want to.

10) OPTIONAL: If you need to color a tiny bit of dough for the vessels, you can use a Sharpie to add color.

11) Make very, very thin "snakes" and apply tiny blood vessels to the cerebrum. (Talk about why blood is so important to the brain, bringing oxygen and nutrients and carrying away wastes.)

12) Stick the magnets to the back very carefully, without crushing the dough on the front. Try not to cover words.

13) Let project dry for several days.

parietal lobe
sensory cortex
motor cortex
frontal lobe
cingulate gyrus
corpus callosum
fornix
"empty" space
thalamus
hypothalamus
hippocampus
amygdala
olfactory bulb
pituitary
mid-brain
occipital lobe
cerebellum
pons
(left) temporal lobe
medulla oblongata

parietal lobe
sensory cortex
motor cortex
frontal lobe
cingulate gyrus
corpus callosum
fornix
"empty" space
thalamus
hypothalamus
hippocampus
amygdala
olfactory bulb
pituitary
mid-brain
occipital lobe
cerebellum
pons
(left) temporal lobe
medulla oblongata

parietal lobe
sensory cortex
motor cortex
frontal lobe
cingulate gyrus
corpus callosum
fornix
"empty" space
thalamus
hypothalamus
hippocampus
amygdala
olfactory bulb
pituitary
mid-brain
occipital lobe
cerebellum
pons
(left) temporal lobe
medulla oblongata

parietal lobe
sensory cortex
motor cortex
frontal lobe
cingulate gyrus
corpus callosum
fornix
"empty" space
thalamus
hypothalamus
hippocampus
amygdala
olfactory bulb
pituitary
mid-brain
occipital lobe
cerebellum
pons
(left) temporal lobe
medulla oblongata

CHAPTER 5

Activity idea 5A: Make an edible model of a neuron

You will need:
- large and small marshmallows, and
- Twizzlers "Peel 'n' Pull" red licorice.
- a toothpick might also come in handy for poking holes in the marshmallow
- optional: "fruit leather" (the kind that rolls up)

This illustration shows the general idea of how to make the neuron. Use a large marshmallow for the cell body and small marshmallows for the myelin sheaths. To get the small marshmallows on the licorice string, you can either poke a lengthwise hole with the toothpick, then try to slide the licorice though, or you may want to slice the small marshmallow to the center, wrap it around the licorice, then pinch it closed again. A fresh marshmallow is pretty sticky on the inside and it should stick back together fairly well. (Another option would be to use "fruit leather" rolled up around axon, like Schwann cells roll around their axons.)

The Peel 'n' Pull licorice is softer than the old "shoestring" red licorice. Fresh Peel 'n' Pulls, right out of the bag, can be molded and grafted. You can make dendrite branches by grafting together small lengths of licorice and firmly pressing (even kneading) the joints until they are securely attached. Don't forget to mold the synaptic knobs at the ends of the axon.

For more model ideas, check out "Neuroscience for Kids" www.facutly.washington.edu/chudler/neurok.html

Activity idea 5B: Art project based on brain cells

(There is a video demonstration of this project posted on the Brain playlist on the YouTube channel.)

You will need:
- paper
- watercolor paint
- a straw for each student

NOTE: Consider showing some examples of neuron art before beginning this project. A good place to start is with an image search using key words "Greg Dunn ink paintings" or "Greg Dunn scroll paintings." You can also go to www.gregadunn.com.

Greg was a student majoring in neuroscience when he discovered the art form you are about to do. He realized that these "blown" ink paintings captured the shape of denrites very nicely. He kept practicing and found ways to make more complex and iteresting designs. When someone asked to buy one of this paintings, he realized there might be a market for his scientific art. Now he works full time as an artist, always staying with the theme of brain cells. He began experimenting with other media and pioneered the use of fiberoptic etchings. His largest fiberoptic work, called "Self Reflected" hangs in the Franklin Institute in Philadelpha, PA. (Even for this etching, he started with patterns created by blown ink.)

Mix the watercolor paint with enough water so that it is a very watery mixture. Put one large drop of this paint mixture on the paper and use a straw to blow out little “arms” from the droplet, looking like dendrites on a neuron. If there is even a small droplet at the ends of these “arms” blow on those, also, creating branches off the branches.

If you want to add some glial cells around your neuron(s) you could use different color and start the droplet in an empty space around your original neuron.

Activity idea 5C: Neuron relay race

Have the students lie on the floor in a line with their hands over their heads. One person’s feet should touch the next person’s hands. You can use two lines if you want it to be a race, one for just a fun demo. Have the nerve impulse represented by wiggling of hands or feet. The instructor makes the signal start by touching the first player’s hands. As soon as the first player feels the touch, they then wiggle their feet. Player two feels the foot wiggle with his hands, then wiggles his feet. Player three senses the second player’s feet wiggling and then player three wiggles his feet, and so on down the line to the last player.

Activity idea 5D: Do the domino demonstration that was mentioned in the text

You will need a set of dominoes and at least one rod of some kind (a dowel rod over a foot in length, if possible, but even a ruler or a long pencil will do). Make two rallies: a normal one consisting of all dominoes, and the other with at least one section replaced by a rod. You can use more than one rod section and you can make the rallies as long as you want to, as long as they are the same length. Start them both at the same time and watch how much faster the line with the rod(s) goes. It really works!

Activity idea 5E: Draw a neuron from scratch, as an art project

There is a video posted on the Brain Curriculum playlist that does a step-by-step drawing lesson. The video is about 18 minutes long, but you might need to pause a few times in the middle if you are working with a group.

You can go to the video directly by using this address:
https://youtu.be/td7-IwbEc5A

CHAPTER 6

Activity idea 6A: Make a human neuronal network (a group activity)

You will need a large area with no furniture (or you can work around furniture?) and as many players as possible. You might also want to have available something harmless that can be used for action, such as a cotton ball to toss in the air, a bell to ring, etc.

Have all players lie down on the floor on their backs, so they are looking up at the ceiling. They must arrange themselves so that each player has at least one hand touching someone's foot. The hands represent dendrites and the feet represent the ends of axons. This cartoon sketch below gives the general idea. Your network won't look exactly like this one.

The adult in charge will select one free arm on the outside of the network to be the target. Put your action item in that hand—something harmless to toss in the air or something to make a sound—so that everyone will know when the target has been reached. Then select another hand to be the starting point. The adult will gently wiggle the starting hand to get the impulse started. That first person, whose hand was wiggled, will then wiggle one of his feet, which is touching someone else's hand. (Wiggle just one foot, not both.) That second person will feel the wiggle of the foot against in his hand, and send the impulse on by wiggling one of his feet (one, not both). The wiggle signal continues, from hand to foot, hand to foot, across the room. No one can see what is going on because they are all lying on their backs looking at the ceiling, so trying to pass the wiggle signal in the right direction could be tricky! The signal may not take the most direct route. When the person who is the target cell feels the wiggle in the foot that is touching one of his hands, he then uses the free hand to do whatever the action is (toss the ball, ring the bell, etc.).

Try the same starting and ending point again, and see if the network becomes more efficient the second or third try. Then try a different starting and ending point. Does the network get better the more it works together?

Activity idea 6B: Neuron network relay race

You will need:
- a fairly large space
- a bag of cotton balls
- some quick-release painters' masking tape
- optional: plastic drinking straws for playing use when blowing the cotton balls

Use the masking tape to mark off neurons on the floor. You will be making several neurons, but the exact number is not important. They can be any length, but if you have enough space, make them at least 8 feet (3 m). Make a short "T" at each end so that the ends are clearly defined. (Make the T's long enough so you will be able to tell when the cotton balls cross the line.) Make a gap between the ends of the neurons, to represent the synaptic gap. It's easier if the neurons are straight, but if you are trying to squeeze them into a room, you could make them bend or turn corners. Also use the tape to make a finish line at the end.

Put cotton balls on the axon side of each neuron. You can use any number of cotton balls, as long as each neuron has the same. If you want to race two teams at a time, you will have to make two lines of neurons.

Players will be stationed at the beginning of each neuron. Each player will crawl along the length of their neuron (representing the action potential going down the axon) until they reach the synapse, at which point they must blow the cotton balls across. (The cotton balls represent any type of neurotransmitters) As soon as all the cotton balls are across the gap, the next player starts crawling.

Option: Give each player a straw to blow through. This allows a targeted stream of air at each ball. You might want to try both ways ahead of time and determine which one will work best in your situation. Or, do the relay twice, once without straws and then once with them.

CHAPTER 7

Activity idea 7A: Demonstration of short-term memory limit

If you teaching a group, you will need the students to work together in pairs. Each student will need a copy of one of the sets of numbers below. Make sure the partners have different number sheets. The first person reads the first line of numbers to his partner (slowly, perhaps a number every second). His partner then tries to repeat exactly what he just heard. If successful, the first person goes on to the second line. If the partner can repeat that one perfectly, go on to the next one. Keep going until the partner can no longer hold all the numbers in his memory. Then switch places and repeat the process.

Expected result is that a student will not be able to repeat a line that has more than 7 or 8 numbers. In the event that a student sucessfully reaches the last line, this indicates that they were able to do fast chunking in some way. They may have quickly combined numbers so that (using the example of the last line in the first set) they are remembering “62, 84, 21, 75, 93” which is only 5 items. Or, if three of the numbers create a sequence they are familiar with (part of their phone number, for example), those three numbers will instantly become a chunk.

3 6 2 9

7 1 4 2 6

2 8 5 9 2 6

5 3 2 6 8 3 7

4 6 1 9 2 5 4 3

7 4 3 8 2 5 9 1 4

6 2 8 4 2 1 7 5 9 3

8 5 2 6

5 1 8 4 7

2 4 9 3 1 6

4 6 9 2 1 5 4

9 5 3 2 6 7 8 3

2 8 1 6 5 3 7 9 4

5 7 2 4 9 6 3 7 2 5

Activity idea 7B: Another way to demonstrate short-term memory limit (a "get-up-and-move" game)

In this memory demonstration you will use bodily motions instead of lists of numbers. You can do this as a group, with the leader doing the series of motions and everyone else trying to imitate. In order to make this more of kinetic memory exercise, and not just visual, the leader should let the players do each motion along with them as the series is being presented. So there would be a brief pause between each motion as the students repeat what they just saw. Then, the players will be asked to do the series of moves again, this time with no prompts, just trying to remember the whole series they just did.

If you anticipate that your students will want to do this game several times, prepare a few other lists of actions. Don't rely on making it up on the spot because you'll find the leader has just as much trouble remembering as the players!

DON'T SAY THESE WORDS, JUST DO THE ACTION:

jog, sniff, blink, wave

jumping jack, clap, sniff, wink, swing arms in circle

blink, clap, swing arms in circle, wave, jog, sniff

jog, swing arms in circle, clap, sniff, wave, jumping jack, nod head

sniff, wave, jumping jack, clap, wave, jog, blink, swing arms in circle, wink

wave, swing arms in circle, nod, wink, wave, blink, clap, sniff, jog

wave, sniff, nod, jumping jack, swing arms in circle, blink, clap, jog, wink, wave

Activity idea 7C: Play a classic memory game

Play the classic game where you put objects on a tray, give players 30 seconds to study the tray, then take the tray away and have them write down as many objects as they can remember. This game does not correspond to the first two short-term memory demonstrations. There is enough time in this game for the players to tap into the edge of long-term memory. They can look at objects several times, producing repetition, which transfers to long-term. (Remember, some long-term is still relatively short.)

After revealing the game is over, considering "debriefing" by having a conversation while looking at the tray of objects. Have the students give their ideas about tricks that could be used to help remember. Could any of the objects be grouped together, allowing for some chunking?

Activity idea 7D: Analyze the results of the first three games

Ask the students which one of the memory games they felt most comfortable with, or did the best at. If the student is an audio learner, they will likely choose the first game. If the student is a kinetic learner, they will likely choose the second. If visual, they will choose the third game. If your students did the learning style survey in chapter 7.5, compare their answers here to the their results on the survey. Is there any correlation?

Activity idea 7E: Another memory experiment: the role of episodic memory (place and time)

In this experiment, students will test the theory that being in the original location where you learned something provides better recall than being in another location. Send each student to a particular location: the corner of a certain room, a place outdoors, in a car, in a closet or even sitting under a blanket. It must be a place where they don't usually sit for class or for doing school work.

Provide them with the list below and have them study it for two minutes. They can use any memory tricks they want to, repetition, grouping, "loci," or whatever works for them. At the end of two minutes, have them come back to the room where they usually do their work. Have them try to write down as many words as they can remember. Then, have them return to the location where they did the memorizing and see if they can remember and write down any additional words. Does being in the original location spark any more memory?

Dog	Please	Swinging	Mother
Mouse	Running	About	Activity
Spoon	Fingernail	Money	Explode
Shelf	Try	Pretzel	Brain
Thief	Present	Math	Lunch
Anger	Map	Doctor	Forward
Keyboard	Distribute	Puzzle	Door
Grow	Pizza	North	Memorize

Afterwards, make a list of words that everyone remembered, and a list of words no one remembered. Do you have any theories about these results? (Not really any right or wrong answers here, although they may be likely to come up with some theories that are more valid than others. It makes a great classroom conversation.)

EXTENSION: Can anyone think of a clever way to use the "loci" method to memorize the list above?

Activity idea 7F: Play a memory game that reviews information about brain parts

Use the following pattern pages to make a "Concentration" game that reinforces their learning about brain parts. Copy the pattern pages onto card stock, then cut the cards apart. This is the classic game where you lay the cards out, face down,arranged in a large square or rectangle so that you can see every card, then each player's turn consists of turning over two cards. If they match, he keeps them; if not, he puts them back.

You may choose which cards to use for this game. You need not use them all. If you have younger or less skilled players, choose just the cards you want them to review.

MAKE ONE COPY ON CARD STOCK

MEDULLA OBLONGATA	PONS	MID-BRAIN	CORPUS CALLOSUM
PITUITARY	AMYGDALA	HIPPOCAMPUS	FORNIX
THALAMUS	HYPO-THALAMUS	VENTRICLE (empty space)	OLFACTORY BULB
CINGULATE GYRUS	CEREBELLUM	OCCIPITAL LOBE	PARIETAL LOBE
SENSORY CORTEX	MOTOR CORTEX	FRONTAL LOBE	TEMPORAL LOBE

MAKE ONE COPY ON CARD STOCK (Do not put word on reverse side of pictues.)

CHAPTER 8

Activity idea 8A: Map out the nervous system with yarn

You will need:
- some yarn (any color)
- a pair of scissors
- some tape

You can do this activity as a demonstration in front of a class, or as a lab activity with students working in pairs.

Use the sketch below as a general guideline for where to put yarn. The yarn will represent nerves running down the spinal cord and out to various limbs and organs. You can choose whether to have each nerve run all the way from the neck, down the cord, and out to a limb, or just simply out from the cord. In the latter case, you will want to start by placing a line of yarn down the spine.
NOTE: The spinal cord (inside the spinal column) stops at the bottom of the lumbar vertebrae.

Activity idea 8B: Find the distance between nerve endings in the skin

You will need:

- 16 pins
- tape
- two index cards
- scissors
- a ruler marked in millimeters

NOTE: If you are doing this as a lab with students working in pairs, you will need these materials for each pair of students.

Use the following illustration as your guide to construct the 8 pin cards. (You will want to cut the index cards into smaller pieces.) Make sure to tape the pins securely so they stay in place.

Instructions for lab partners: Have your partner pick up the largest pin card, where the pins are spaced at 40 mm. Close your eyes and have them touch the back of your hand VERY LIGHTLY with the pins. (They might want to tilt the card just a little so that the pins are not facing directly down on the skin.) How many points can you feel? Two? Now have your partner take the next smallest card, 30 mm, and touch the back of your hand again. Can you still feel two points? Try 20, 10, 5, 3, 1. At which spacing do you feel only one point? Try the experiment again with these body parts: fingertip, arm, cheek, lip, lower back, lower leg, scalp. How do your results compare? In places where you can still feel two points all the way down to 5 or 3 millimeters, you have nerve endings that are very close together. In places where you very quickly lose the sensation of two points, this means that nerve endings are less abundant and you therefore have less sensitivity in these areas.

Here is a picture of what is happening:

In this case, the nerve endings are spaced very closely and two signals are being sent to the brain.

In this case, the nerve endings are spaced far apart, and only one signal is being sent to the brain.

Which areas of your body are the most sensitive? Does this correspond to their function? How many nerve endings do you need on your arm in comparison to your fingertips, and why?

Activity idea 8C: Reflex relay (group game)

You will need a large playing area, the larger the better. You will also need two lines of some kind. They can be chalk lines outside, or masking tape inside, or whatever you want. One of these lines will represent the spinal cord and the other will represent a body part; you decide which will be which.

Divide the players into pairs. The players will represent the electrical signals traveling back and forth from the spine during a reflex. One player will be the incoming signal, going to the spine, and the other players will be the outgoing signal, going back to the body part.

The race director says, "Ready, set, ouch!" At the word "ouch" the incoming player races over to the spine, and tags their partner. The outgoing signal then races to the body part. The fastest two-person relay team wins. This is a short race, and can be repeated as many times as time or interest allows. (You may want to scramble the teams every time a new race starts so that you get different winners each time.)

Activity idea 8D: Test a reflex using a dollar bill

This activity must be done with a partner—you can't do it to yourself. The person who is the test subject sits with their arm resting on a table, but with their hand off the table. The hand should be opened as shown in the picture.

The "scientist" holds a dollar bill so that the middle of the bill is right between the fingers. (Make sure the fingers are reasonably far enough apart.) Without any advance warning, the scientists drops the bill. The test subject tries to catch the bill. The laws of physics tell us that the force of gravity will pull the bill down faster than the rate at which the nervous system can respond. In other words, it is impossible to catch the bill. If the test subject catches it, they probably got lucky and anticipated the drop by a split second. You will often see this happen—the test subject will "jump the gun" and close their hand even before the bill has been dropped.

Activity idea 8E: Demonstrate the importance of water to the receptors in the tongue

You will need some crackers and a roll of paper towels.

Tell each student to take a paper towel and press it to their tongue several times to get as much moisture off as possible. When the tongue feels as dry as possible (it feels weird) then put a cracker on the tongue and see if there is any taste sensation. There is likely to be very little taste. Let the cracker sit in the mouth until saliva starts to collect again, and notice how the tongue is able to taste again. This is because water molecules are essential to the ability of the taste receptors to function. The food must be adequately dissolved in water to be able to stick to the receptor sites and thereby stimulate the nerve endings to send signals to the brain.

CHAPTER 9

Activity idea 9A: Make a dream

This game is meant to simulate one theory about where dreams come from. The theory says that your various brain parts randomly fire off electrical signals while you are asleep, as part of your brain's nightly "defragging" operation. As part of this operation, various brain parts fire off signals. This results in fragmented pieces of memories being brought up to your frontal lobe Little bits and pieces of totally unrelated memories come into your frontal lobe all at once, and your poor frontal lobe has to try to make sense of them. Of course, they don't make sense at all, so the best your frontal lobe can do is to try to string them together in some sort of bizarre story line. Remember, this is just a theory, and there are other theories out there, too. However, this theory does make a fun simulation game!

You will need:

- a stack of index cards
- pencils
- six bags or boxes

Label the bags or boxes: PEOPLE, PLACES, FEELINGS, SMELLS/TASTES, SOUNDS, ACTIONS. Have each student write at least two cards for each category and put them in the appropriate boxes. They should write just single words, or very short phrases, nothing longer than half a dozen words.

You can have all students play together as a group, or you can divide the students into smaller groups so that each student can have more than one turn. Have the students in each group sit in a circle. The first player gets up and takes one card from each bag. He then sits back down in his place and reads the six cards out loud. He then must play the part of the frontal lobe and come up with a sentence or two that includes all the words on all the cards. (Just a sentence or two, not a complete storyline!) After everyone has giggled and laughed at the first person's funny sentence it is then the second player's turn. Play continues until everyone has had a turn. (Who says science can't be humorous sometimes?!)

Activity idea 9B: A cooperative dream/memory game

Have all players sit in a circle. The first person starts by saying, "I had a dream about..." and then adds a person, place or thing. For example, "I had a dream about my uncle Fred," or "I had a dream about Antarctica," or "I had a dream about a swimming pool." The second player then has to repeat what the first player said, and then add something else. For example, "I had a dream about my uncle Fred playing basketball." The third player has to repeat what the second just said, then add something else. For example, "I had a dream about my uncle Fred playing basketball with a tiger." The fourth person might say, "I had a dream about my uncle Fred playing basketball with a tiger while wearing his scuba suit." The play continues until all players have had at least one turn For a second round, start with the person who was last in the first round, so it evens out.

Activity idea 9C: Class demonstration idea using imaginative play (ideal for younger students)

If you want a fun and interesting way to introduce the topic of EEG patterns in sleep, try this simple way of simulating an EEG machine. (You are basically acting out the information in the first part of the chapter.)

You will need:

- some yarn
- some clips (will be lightly clipped to a voluteer's hair)
- tape
- a white or black board, and the appropriate drawing tool to write on it.
- optional: table, or a few chairs that can be lined up to make a place to lie down

Cut pieces of yarn and tie a clip onto one end of each piece. Tape the other end to the side of the white or black board. Put the table, or lined-up chairs, close to the white/black board. Have a student lie down on a table or line of chairs. They will pretend to be asleep in a "sleep lab." Clip the clips onto the hair in various places over the scalp. Explain that the yarn represents electrical wires that will pick up electricity made by the brain and display it as squiggles on the EEG screen (the board). Also explain that in real life, the wires must be attached to the scalp, not the hair.

You might want to take a minute to explain the name of the machine: electro-en-cephalo-graph. "Electro" means electricity, "en" means in, "cephalo" means head, and "graph" means picture. Put them together and you have "electricity in head picture." That sounds a lot easier than "electroencephalograph." You might also want to explain what sleep labs are and how researchers use them to find out about sleep.

Now take your drawing implement and start making a beta wave. See the picture in the text to simulate the look of the waves.) Tell your patient to relax and daydream, then start making alpha waves. Now tell your patient to go to sleep (for pretend, of course). As they pretend to go to sleep, make the waves start to get higher and farther apart, like theta waves. Tell your on-lookers that you can tell that the patient is now starting to really fall fast asleep, and draw little spindles in your theta waves. Proceed on to delta waves, explaining that your patient is now in his or her deepest sleep. (If you run out of space on the board, just start a new line below the first one.)

After some delta waves, start to make beta again. Ask the on-lookers what those look like. They will say it looks like the waves while the patient was awake. This is correct! The patient is asleep, however, so we cannot really call them beta waves. We will have to find another name. At this point you may want to take a close-up look at the patient's closed eyes. Tell the on-lookers that you can see (under the eyelids) that the patient's eyes are going back and forth very rapidly. That gives you an idea for the name of these waves. You can call them REM, for Rapid Eye Movement. You can explain that it is during this time that most dreams occur. Then go back to making delta waves, then do some more REM, then more deltas, and so on until you have completed about five REM cycles. Then you can proceed to theta, then to alpha, then to beta as your patient wakes up.

CHAPTER 10

Activity idea 10A: Make your own Rorschach ink blots (Even older students will enjoy this!)

You will need:
- paper
- paint of some kind

If you want your final blots to be water-proof and smear-proof, use acrylic paint. You will also get nicer texture and colors with acrylics than you will with tempera or poster paints. However, these other paints can be used if that's all you have available.

Fold the paper in half, then open it again. Put some random drops of paint on one side, with a few right in the crack. Fold the paper again and press thoroughly. When you open it, you will have your own original ink blot test. It's so much fun, you can't do just one!

NOTE: The Rorschach ink blots were either all black, or black with a little bit of one or two colors added here and there. You can see more Rorschach ink blots if you do an online image search for "ink blot tests."

After they are dry, try them out on classmates. What do they see in your blots? Students can take turns being the "psychologist" and the "patient." It's okay for the "psychologist" make up silly reasons for the "patient" to have seen what they did, as long as the comments are polite and rated "G."

Activity idea 10B: Watch some short videos about various disorders

Check the playlist to see some informational videos about various disorders. The videos have been previewed ahead of time so there is nothing distressing or inappropriate. Not every condition mentioned in the text is represented. If you want to know more about a specific condition, use key words to search and preview the video before watching it with your student(s).

BIBLIOGRAPHY

These are the main books I used for my original research (2007), listed in order of how much I used them:

The Brain and Central Nervous System, from the Reader's Digest series: *Your Body, Your Health*. Published in 2002 by Reader's Digest in Pleasantville, NY. ISBN 0-7621-0436-8

Big Head! by Dr. Pete Rowan. Published in 1998 by Alfred A. Knoff, NY. ISBN 0-679-89018-1

The Human Nervous System; An Anatomic Viewpoint, by Murray L. Barr. Published in 1979 by Harper & Row, Publishers. ISBN 0-06-140312-1

Inside the Brain, by Ronald Kotulak. Published in 1996 by Andrews McMeel Publishing, Kansas City. ISBN 0-8362-3289-5

How the Brain Learns, by David A. Sousa. Published in 2006 by Corwin Press, Thousand Oaks, California. ISBN 1-4129-3661-6

Mapping the Mind, by Rita Carter. Published in 1998 by University of California Press, Berkeley and Los Angeles. ISBN 0-520-22461-2

The Art of Changing the Brain, byJames E. Zull. Published in 2002 by Stylus Publishing, Virginia. ISBN 1-57922-054-1

Right-Brained Children in a Left-Brained World, by Jeffrey Freed and Laurie Parsons. Published in 1997 by Fireside Books, a division of Simon & Schuster, NY. ISBN 0-684-84793-0

These are the main websites I used, though I did pop in and out of some other minor that are not listed. Also not listed are some YouTube videos I watched, although some of them are posted on the playlist.

Wisconsin Medical Society at www.wisconsinmedicalsociety.org

Howstuffworks.com

"Neuroscience for kids" at www.facutly.washington.edu/chudler/neurok.html

Also many "Wikipedia" articles on brain parts