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THE HUMAN BODY

Understanding the Brain

KATE BOEHM JEROME

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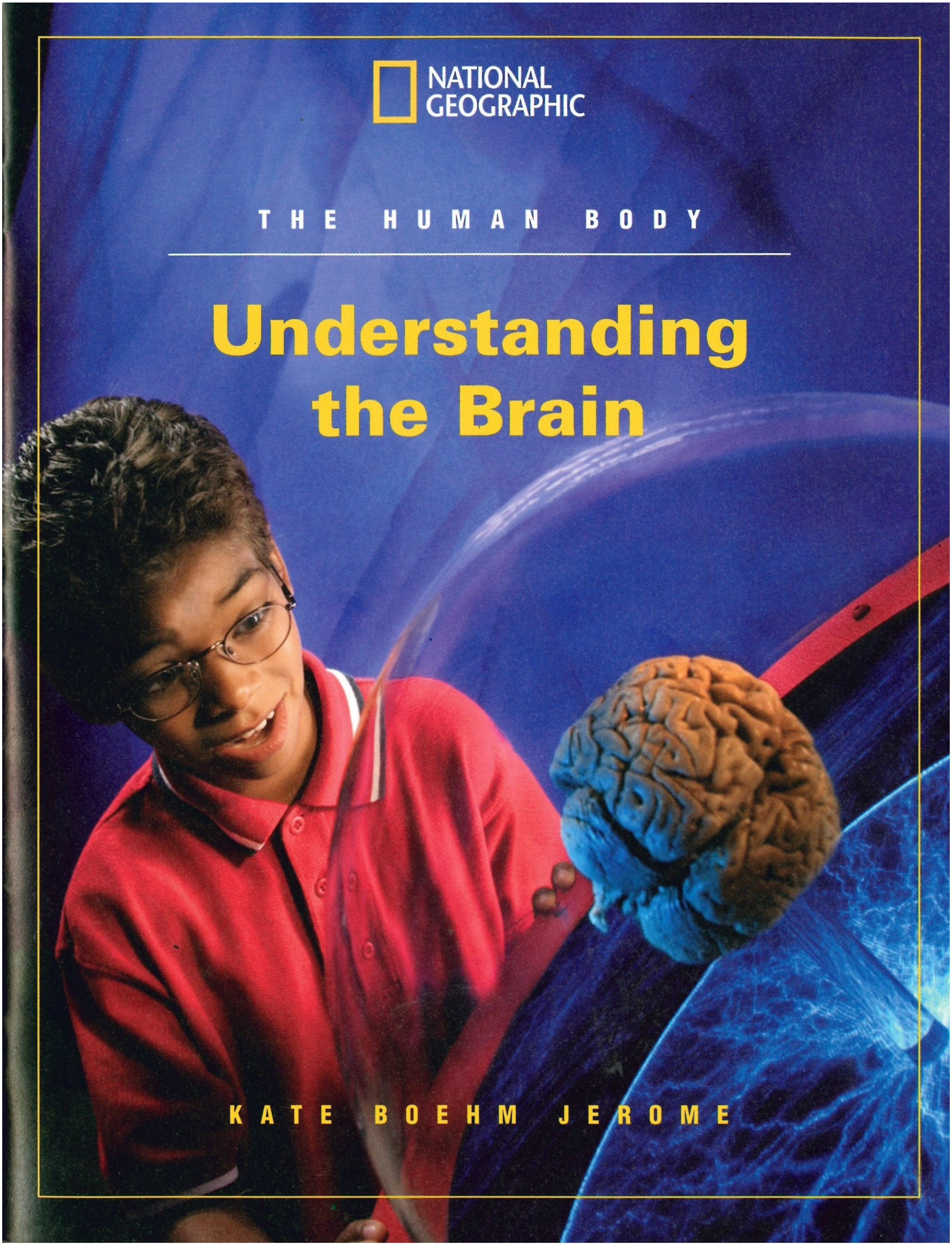
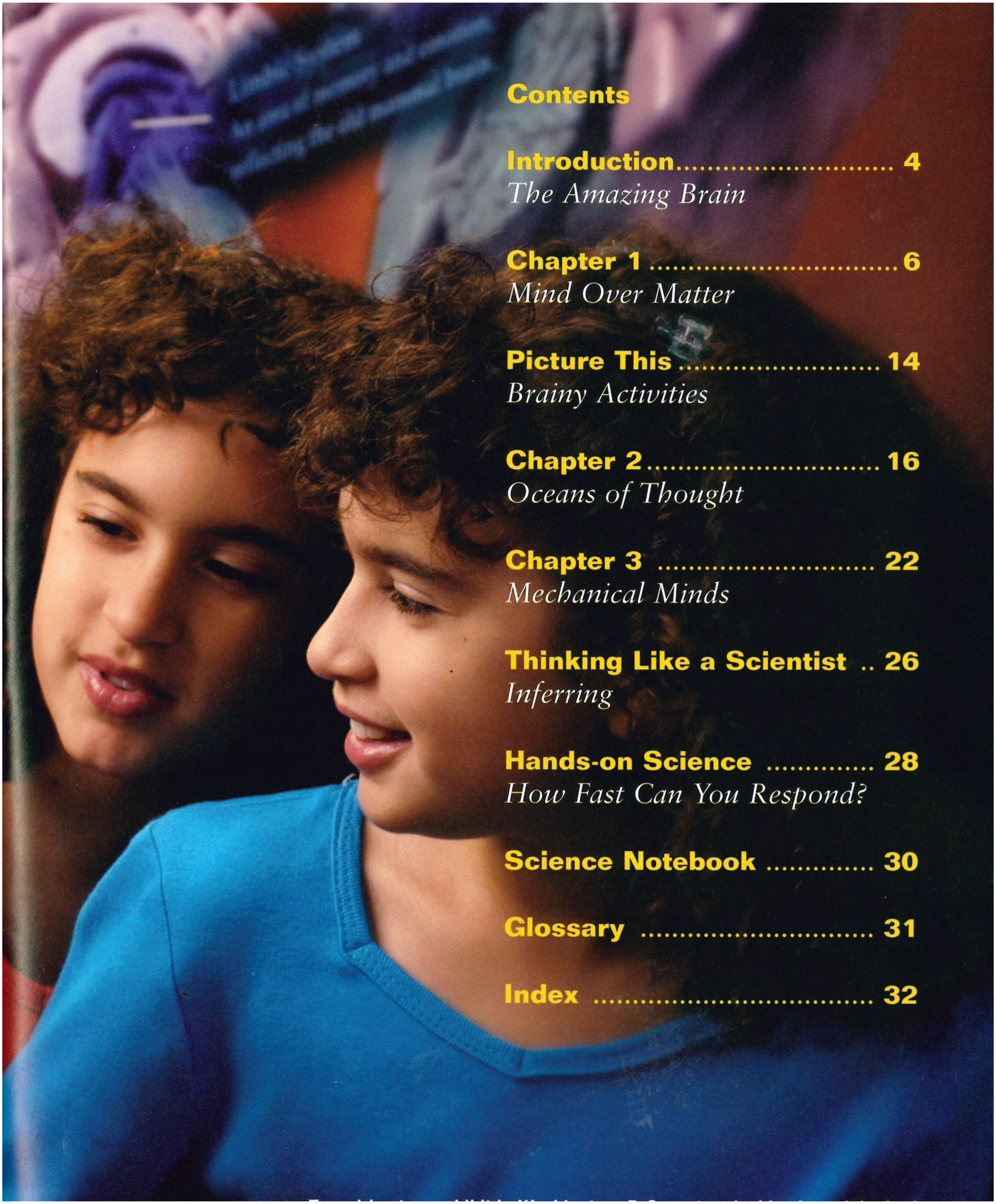




Contents

The Amazing Brain

It's hard to imagine all the things a human brain can do. From playing music, to swinging a hockey stick, to reading this book, your brain is in charge of it all. At full size, it weighs only about 1,450 grams (3 pounds). Yet it is more complex than any computer ever built. Only a brain can imagine a brain!

As you read the words on this page, your brain is doing amazing things. Your brain draws on your experiences and memory to help you understand this book. Not only is it recognizing letters, it also is putting meaning to words. And that's not all.

Even though you are reading, your brain is also monitoring the world around you. If your teacher sharply calls your name, your brain will help you make the wise decision to stop reading and look up. There's still more.

Your brain controls activities inside your body that keep you alive. You don't have to worry about remembering to breathe or forgetting to keep your heart beating. That's because your brain is automatically running these systems. Good thing—or forgetfulness might become a fatal disease.

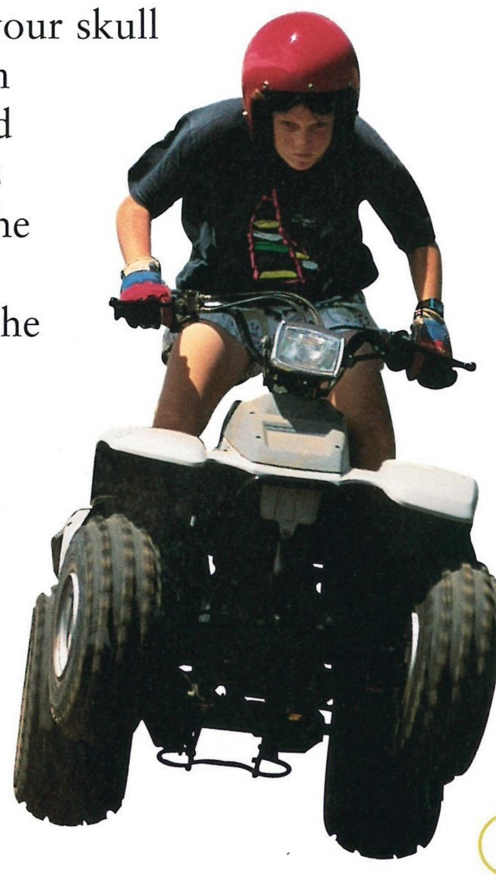
This is a book about your incredible brain. Scientists are just beginning to understand how it works. It's still a challenge to think about how we think.

Chapter 1 Mind Over Matter

What do batting a baseball, mountain biking on trails, leaping rails on horseback, and charging over hills in a four-wheeler have in common? You guessed it—helmets!

Activities like these can be thrilling, but remember that with action comes accidents. Suppose you're speeding down a bike path and WHAM! Your tire hits a rock and you're sent into the air. An accident like this could be deadly. But luckily you were wearing your safety helmet and didn't get seriously hurt. Each year thousands of others are not so lucky. In the United States, bicycle accidents are a common cause of head injuries for kids aged 5 to 12 years old. So when you grab a helmet, you're using your head to protect your brain.

Head, neck, and back injuries can be particularly serious. Why? Because they risk damaging the brain and its nerve network—the system that controls nearly everything we do. That's why it's great that your brain has some built-in protection. The 28 hard bones of your skull form a protective shell around the brain. In addition, your brain is supported in a liquid cushion inside the skull. This cushion helps absorb shock waves caused by a blow to the head. The nerves extending from the brain are protected by the bones running down the middle of your back. All in all, your brain and nerves are well protected.



In this chapter we'll explore how this main control system works. Lucky for us, the brain and its nerve network never completely shut down, even when we're sleeping.

Focus On

Thelma Estrin: A Brainy Engineer

When Thelma Estrin studied engineering in college in the late 1940s, many of her professors didn't take her seriously. Not many women at that time wanted to become engineers. But Estrin was different. By 1951, Estrin had received her Ph.D. in electrical engineering. She joined the Brain Research Institute at the University of California in Los Angeles in 1960. There she started the Data Processing Laboratory. She published some of the first papers on how to map the brain with the help of computers. Estrin was also among the first people to use computers to solve problems in health care.

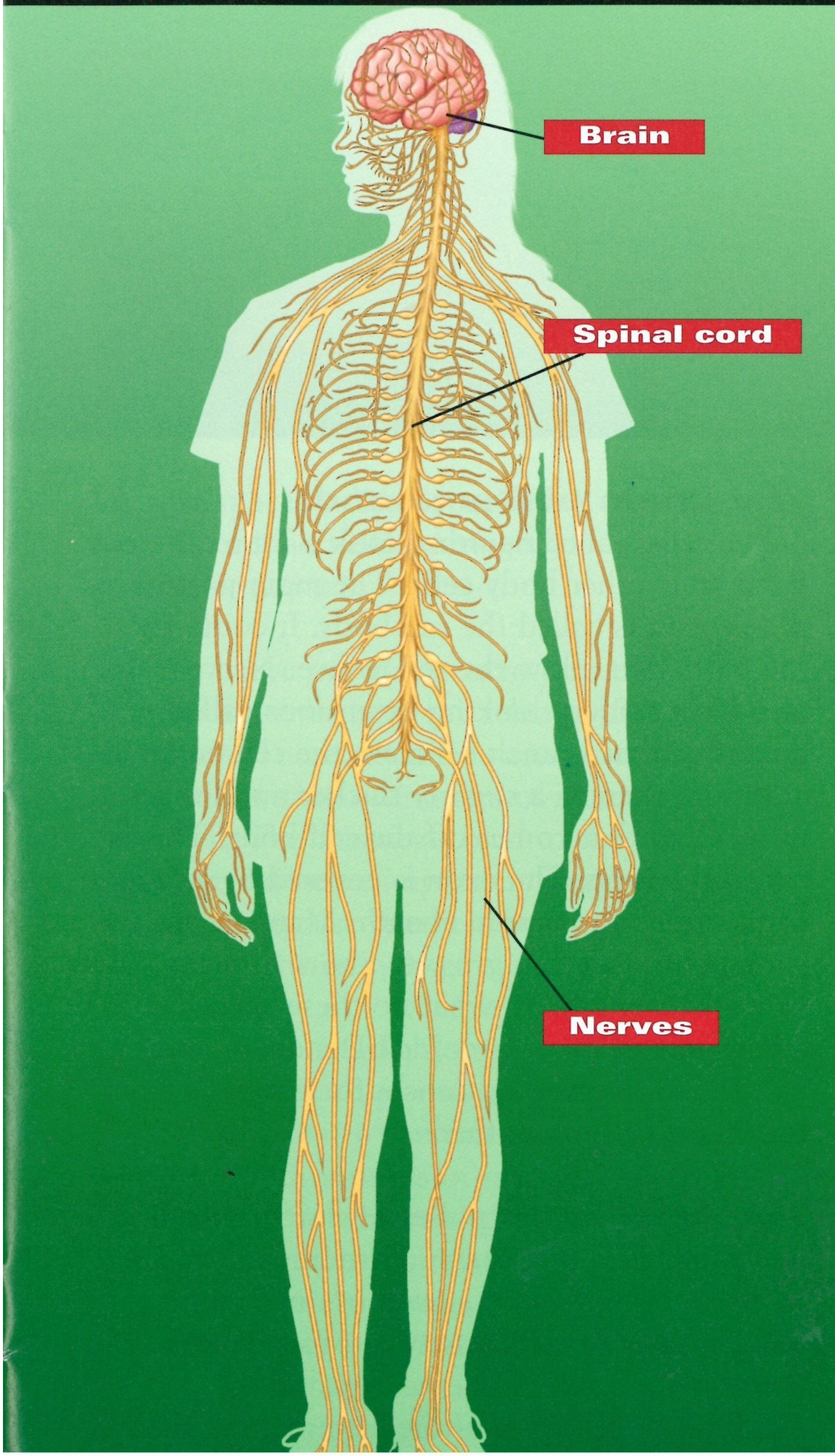
You've Got a Lot of Nerve...

Your brain directs all of your body's activities. How does information get to and from an organ that sits deep inside your skull? The answer is the **nervous system**. The nervous system is a communication network that runs through your whole body. There are two main parts to it. The first part is called the **central nervous system**. The central nervous system is your body's control center. It is made of your brain and the spinal cord that runs down your back.

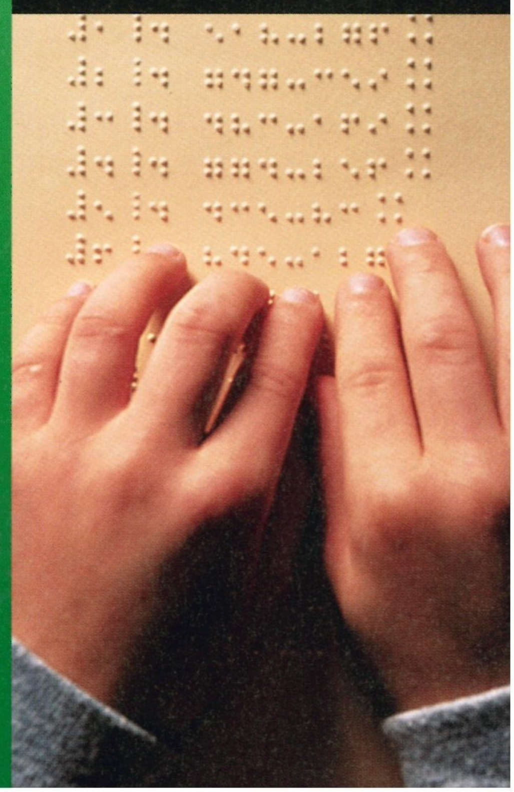
The second part is called the **peripheral nervous system**. It is made of the billions of nerves that branch out from your spinal cord to different parts of your body. These nerves carry messages between the body and the central nervous system. When nerves pick up a **stimulus**, they send that information to your brain. A stimulus is something around you that causes you to react. If someone calls your name, the nerves inside your ears pick up that stimulus and send the sound information to the brain. Your brain recognizes the sound as your name. Then your brain sends a message to your body telling it to turn around to see who's calling you.

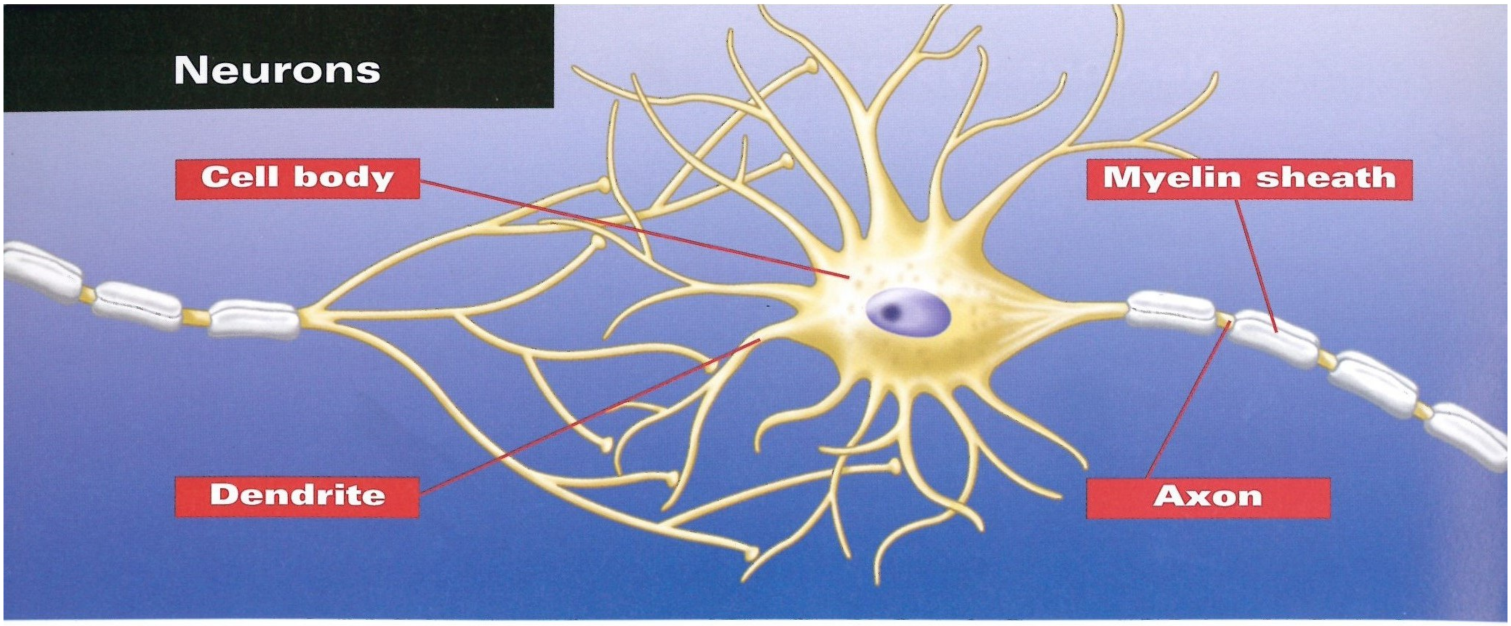
Even though thousands of nerves were used to send the message to the brain, most of those nerves never even touched each other. So how do messages get through? Let's take a close-up look at nerves to find out.

Nervous System



The nervous system makes sense of stimuli, such as the sounds in a hearing test (above) and the bumps that make up Braille (below).

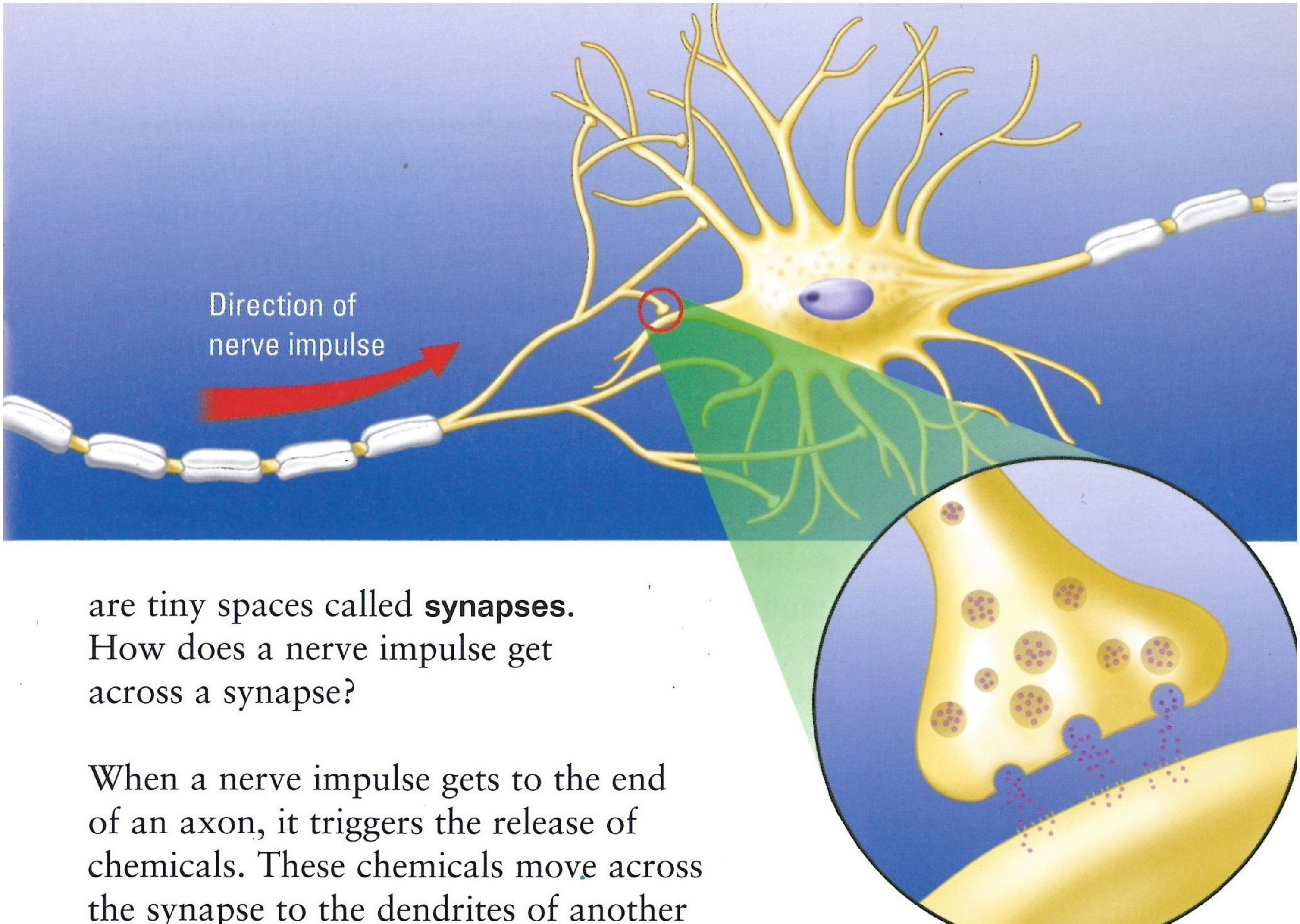




The Chain of Command

Nerve cells, called **neurons**, look a little different from your other body cells. The main part of the neuron is called the cell body. It contains the parts that allow the cell to live. Nerve cells also have spidery-looking extensions called **dendrites** that branch off from the cell body. In addition, there is a slightly thicker and longer nerve fiber that comes off the cell body. This is called the **axon**. The axon is covered by a layer of fat called the **myelin sheath**. Many axons are short, but some can grow to about a meter (3 feet) in length. So what do these special extensions of the neuron do? Dendrites and axons are involved in transporting signals from one nerve cell to another.

These signals are tiny pulses of electricity called **nerve impulses** that carry information. The nerve impulses move from the axon of one neuron to the dendrites or cell body of another neuron. Between the axon of one neuron and the dendrites or cell body of the next neuron, there



are tiny spaces called **synapses.** How does a nerve impulse get across a synapse?

When a nerve impulse gets to the end of an axon, it triggers the release of chemicals. These chemicals move across the synapse to the dendrites of another nerve cell. The chemicals bind to the dendrites and trigger a nerve impulse in that nerve cell. When the impulse reaches the end of that nerve cell's axon, the relay begins all over again.

When a nerve impulse gets to the end of an axon, chemicals move across the synapse to another nerve cell.

Sounds rather simple, doesn't it? What is amazing is that all of this happens incredibly fast between many neurons. Some neurons have tens of thousands of synapses where they can exchange messages with thousands of other neurons. Even when you are at rest, millions of nerve impulses are moving through the nerve network of your body.

How do nerve impulses travel through the body?

The cerebellum helps you balance.

Your feelings occur in the cerebral cortex.

Using Your Head

The first thing you notice when you look at a brain is all the wrinkles on its surface. Do all these folds serve a purpose? You bet they do. They increase the surface area of the brain. Think about it. If you lay a piece of notebook paper across your hand, one piece of paper will cover your whole outstretched hand. What if you wad that piece of paper up into a tiny ball with lots of folds and wrinkles? You will have room to fit several pieces of paper into your hand. Many brain cells are located on the surface of the brain. So having more surface area allows the brain to store and process more information in the limited space inside your skull.

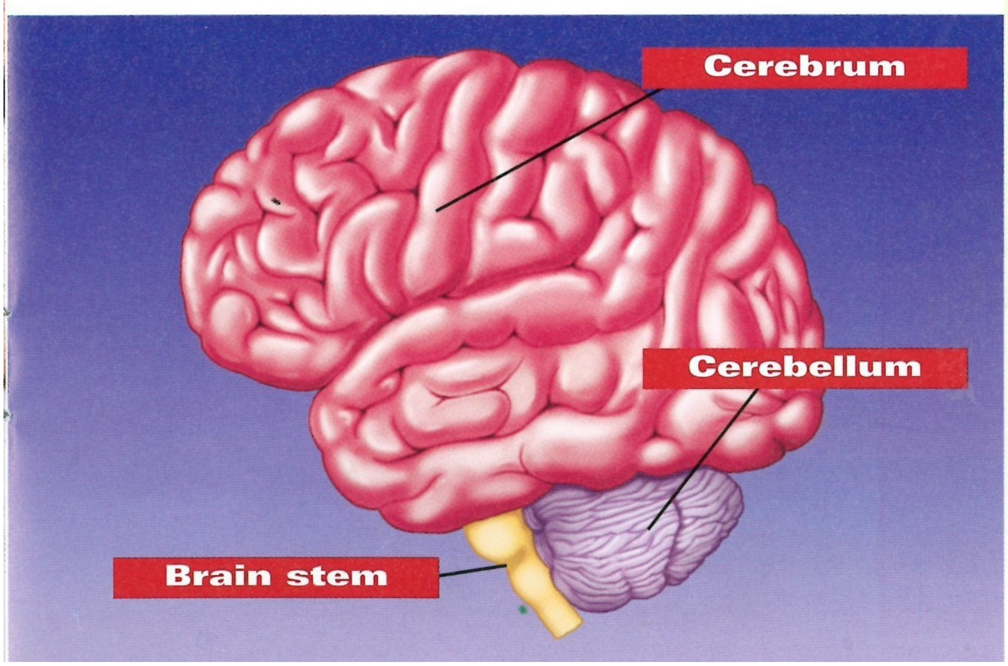
Cerebrum There are several main sections of the brain. The **cerebrum** is the biggest part. It is sometimes called the thinking part because it allows you to do just that—think. Your cerebrum lets you remember your address and imagine the future. It also processes information from your senses and controls voluntary movement such as picking up this book.

Most of our conscious thoughts and feelings occur in the outer layer of the cerebrum, called the cerebral cortex. Although you can't tell from looking at it, parts of the cerebral cortex are specialized to do certain jobs. Scientists know this because when particular areas of the cerebral cortex are damaged, people lose their ability to do certain activities.

Cerebellum The **cerebellum** lies below the cerebrum. This part of your brain coordinates muscle activity and helps you keep your balance. What do you think might happen to an Olympic gymnast if her cerebellum were damaged in an accident?

Brain Stem Another small but important part of the brain is called the **brain stem.** The brain stem lies at the base of the cerebrum and connects the brain to the spinal cord. The brain stem controls breathing and other involuntary functions that keep us alive.

Your brain grows quickly until you're about 18 years old. However, even when a brain stops growing in size, it doesn't stop making connections. In fact, your brain can continue to develop in complexity based on your experiences. Many studies have shown that our brains stay healthiest when they are constantly active. When it comes to brainpower, the phrase "use it or lose it" certainly applies.



Thinking Like a Scientist:

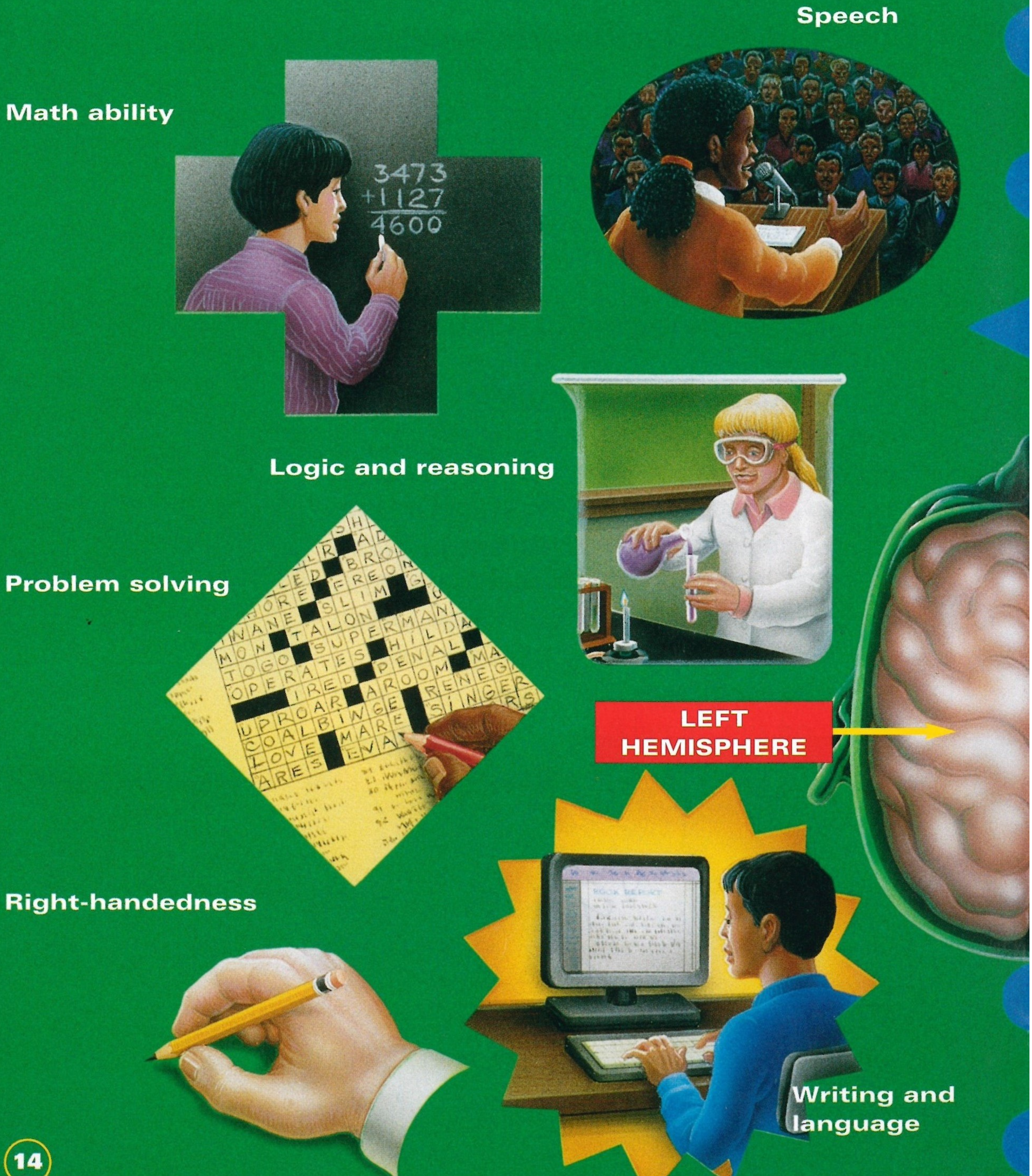
Inferring

Scientists observe and collect information all the time. Then, based on their own experiences, they sometimes **infer** what that information means. Inferring is useful in helping us come to reasonable conclusions.

For example, some of what scientists know about the brain comes from inferring. Suppose a boy has an accident and afterward he has a difficult time balancing as he walks. Scientists might infer that the accident damaged the boy's cerebellum. That's because they've learned through their experience and research that the cerebellum is the part of the brain that helps a person balance.

Picture This

Brainy Activities

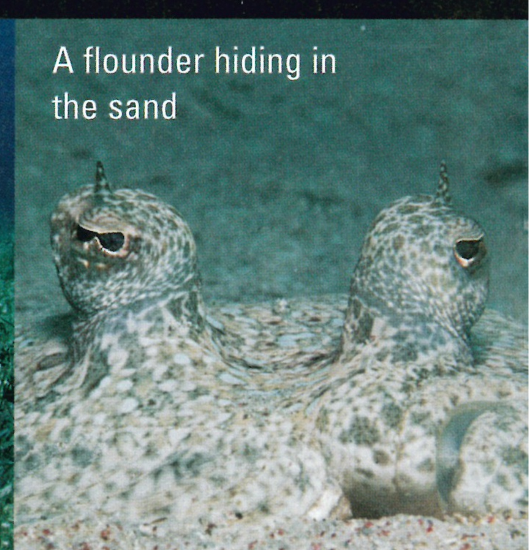


Did you know that your brain has two sides, or hemispheres? The hemispheres work together, but each controls different activities. Your left hemisphere controls the right side of your body. Your right hemisphere controls your body's left side. Each hemisphere influences certain activities, as shown below.

Chapter 2 Oceans of Thought

Sand tiger sharks in the Atlantic Ocean

A shark hunting for food



A flounder hiding in the sand

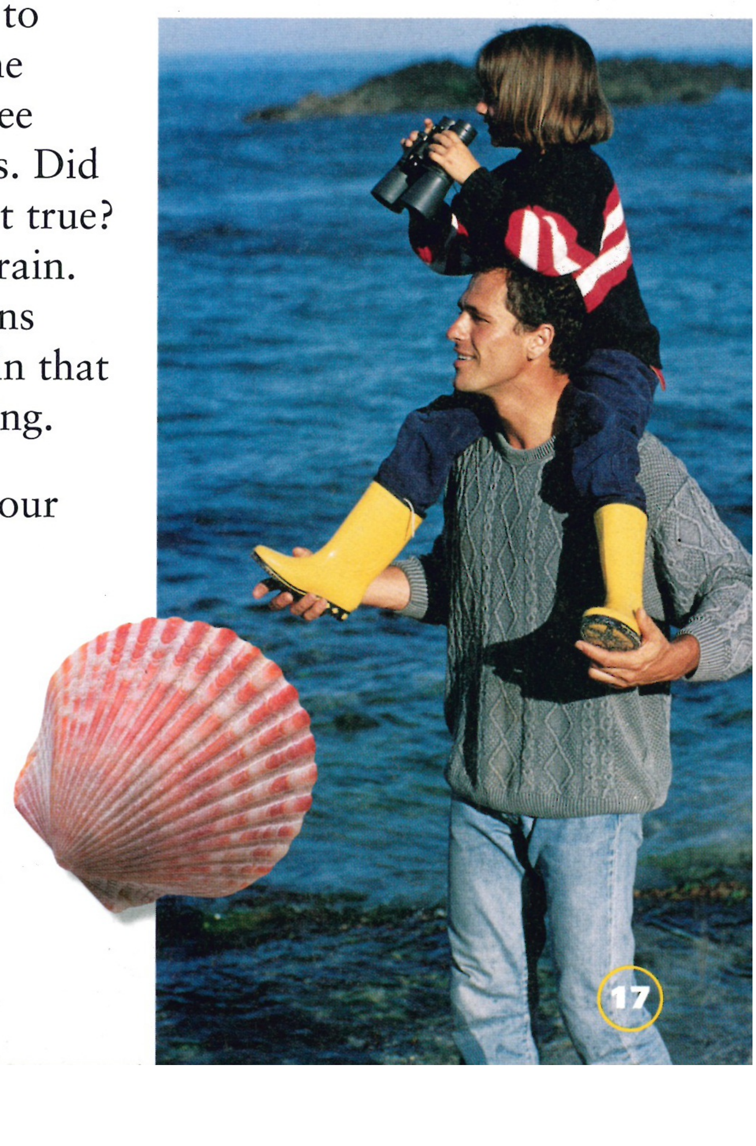
The sand shark swims slowly along the bottom of the ocean. Suddenly it takes a quick bite at the ocean floor. A flounder hiding in the sand becomes the shark's meal. How did the shark know the fish was there without even seeing it?

Sharks have an extra sense that we humans don't have. A shark can detect electric fields with special cells around its head and nose. The sand shark found the fish by detecting the electric field given off from the flounder's tiny heartbeat!

The Senses

Just like sharks, we depend on our senses to survive. Our senses allow us to see, hear, smell, taste, and feel the things in our environment. Each of our sense organs is adapted to take in information and send it to the brain. It is common to say that we see with our eyes and hear with our ears. Did you know that, technically, that's not true? We actually see and hear with our brain. Our eyes, ears, and other sense organs collect information. But it is the brain that sorts out the data and gives it meaning.

In this chapter we will explore how our senses gather information. Then we will look at what the brain does with all this data. In other words, we will learn about how we learn.



Your senses allow you to take in information about the world around you.

I.Q. Interesting Question

Q Why does my room look gray when my lights are out at night?

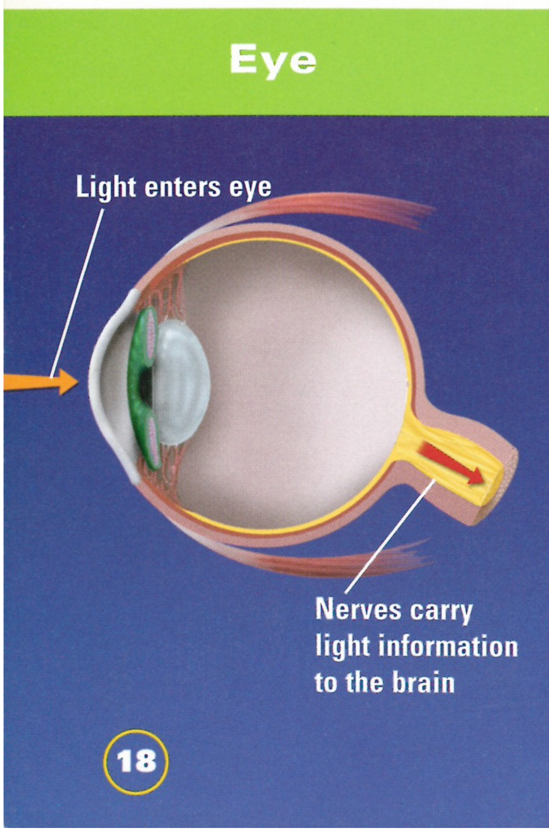
A Seeing has to do with the two kinds of light-sensing cells in your eyes—cones and rods. Cone cells allow you to see color. They don't work well in low light. Rod cells allow you to see shades of gray. They detect light even when it's almost dark. When your room is dark, there isn't enough light for your cone cells to detect color. But there is enough light for your rod cells to see shades of gray.

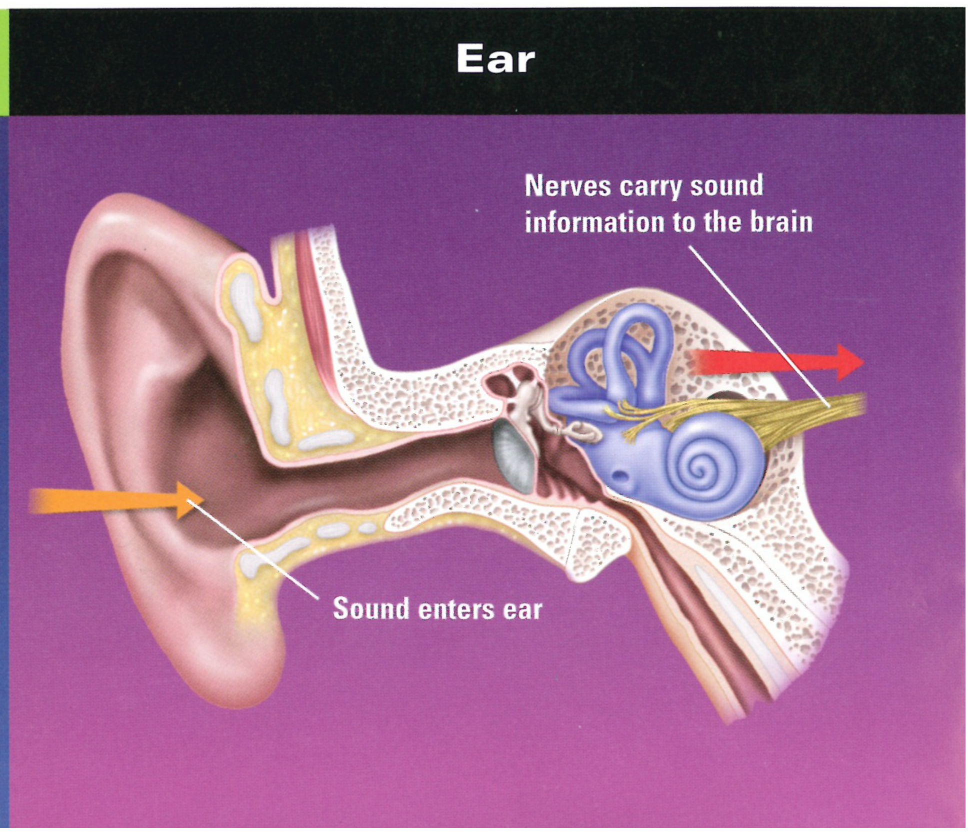
Making Sense of Senses

The human body has millions of cells that gather information. These are called **sensory receptors.** Some of these receptors tell what's going on inside your body. Other sensory receptors tell you what's happening outside your body. Groups of sensory receptors that work to pick up certain kinds of information, such as light or sound, form sense organs. There are five main sense organs that collect data from outside your body.

Eyes Your eyes are the sense organ for vision. The eye detects light, and nerves send that information to the brain. The brain then makes sense of the data.

Ears Your ears are the sense organ that picks up sound. Sound waves enter your ear and vibrate your eardrum. These vibrations are passed





farther into your ear. Then a message is sent by way of the auditory nerve to your brain. Your brain then identifies the sound.

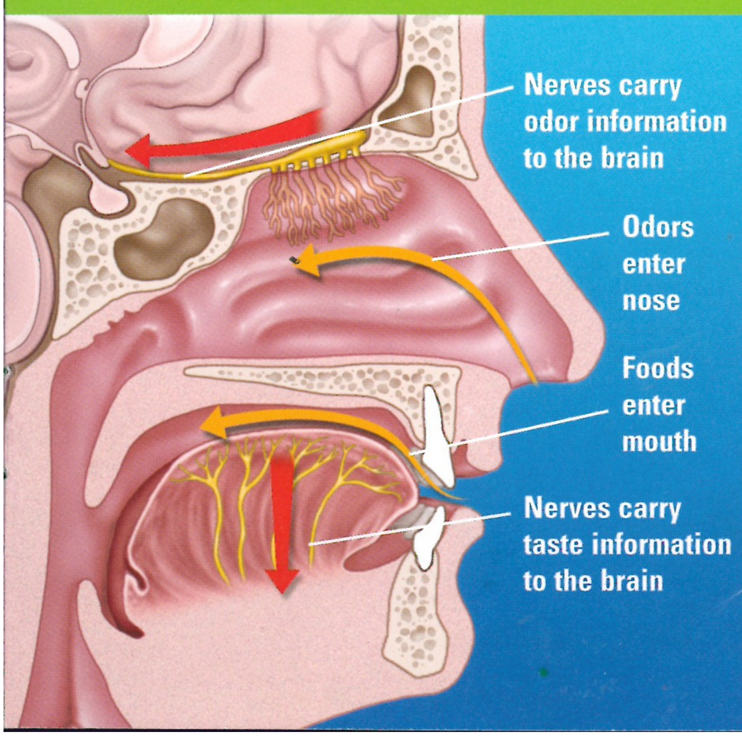
Tongue and Nose Your tongue and nose really work together to form your sense of taste. The taste buds on your tongue sense four main tastes—sweet, sour, bitter, and salty. However, your nose has odor receptors that can recognize up to 10,000 odors. This means that your sense of smell adds to your sense of taste when you eat. That's why foods don't seem to have as much flavor when your nose is stuffed up with a cold.

Skin Your skin is the sense organ that is sensitive to touch. Sensory receptors that detect pain, cold, heat, and pressure are located all over your body, but they are not evenly spaced. Your fingertips are loaded with sense receptors, but the middle of your back doesn't have many.

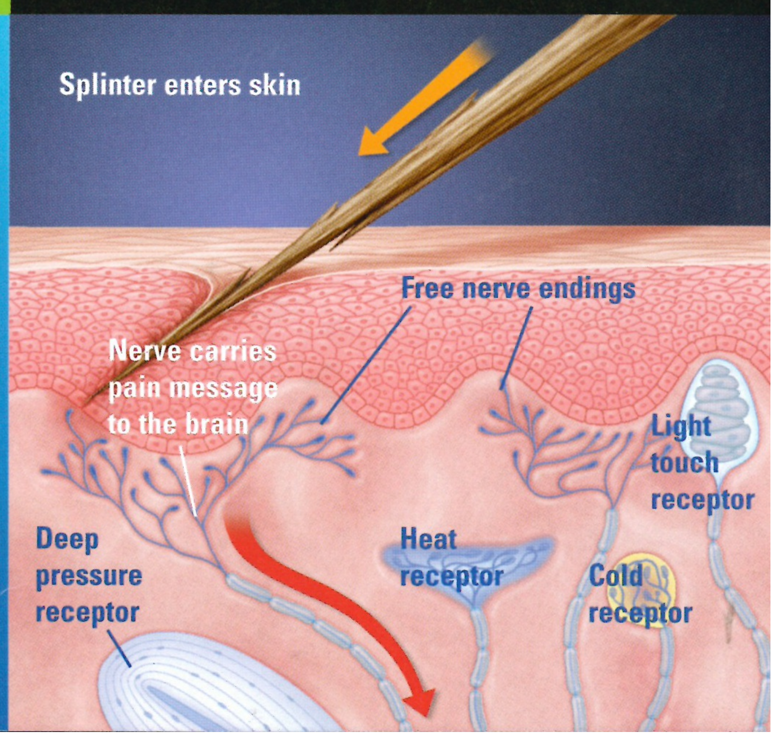
Stay Tuned!

An injury such as a bad burn can seriously damage a person's skin. If an injury is bad enough, the person may need new skin to cover the injury. Today artificial skin can be made for this purpose. Skin cells are grown in a laboratory. Then they are put on the wound so the injury can heal faster. Artificial skin is always being tested for new uses. Stay tuned for new ways that artificial skin is being used and improved.

Tongue and Nose



Skin



Walking and doing puzzles involve procedural memory.

Memory

What does the brain do with all the information it collects? It learns and remembers. In fact, scientists think of learning and remembering as part of the same process. One wouldn't happen without the other. You can think of **memory** as the brain's process of storing learning experiences.

One type of memory is called **procedural memory**. Procedural memory involves actions, habits, and skills that are learned by repetition. You develop a procedural memory by practicing something over and over again. Eventually, your brain and body begin to do it automatically. For example, walking is a procedural memory. You've done it since you were young. Now you don't have to focus on each step you take because your brain has stored the process, or procedure, of walking.

Think about your trumpet lessons or your ballet class. Why do you take them? You guessed it. Lessons help you develop procedural memories. Everything from tying your shoes, to playing an instrument, to learning dance steps, to riding a bike is a procedural memory. Procedural memories are learned slowly, but they are remembered for a long time.

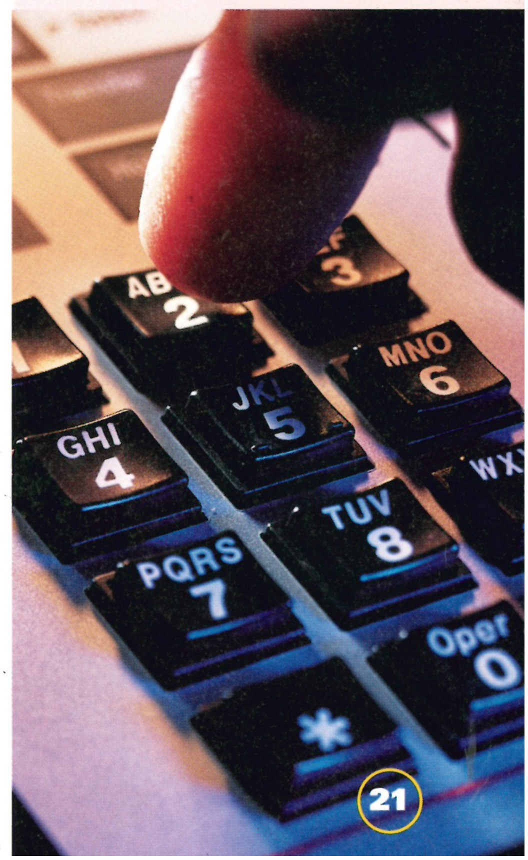
Another kind of memory is called **declarative memory**. This kind of memory is made of facts, figures, names, and events. Just think about studying for a test. When you memorize lots of facts, your brain is storing declarative memories. But beware, declarative memories are easy to form and easy to forget. If you use the information, you can remember it for a long time. If you don't—POOF!—it can seem to disappear from your brain entirely.

When you form a new declarative memory, your brain evaluates an experience and compares it with what you already know. For example, suppose you see a person from your school at the movie theater. It may take a second to remember that person's name. This is because your brain associates that person with school. So it has to work to find the right memory to make sense of the face in the movie theater. Everyday experiences like this one reshape your brain. When you learn something new, you are making new connections between brain cells. That means your brain is constantly making changes at millions of places to store the memory of even a small event.

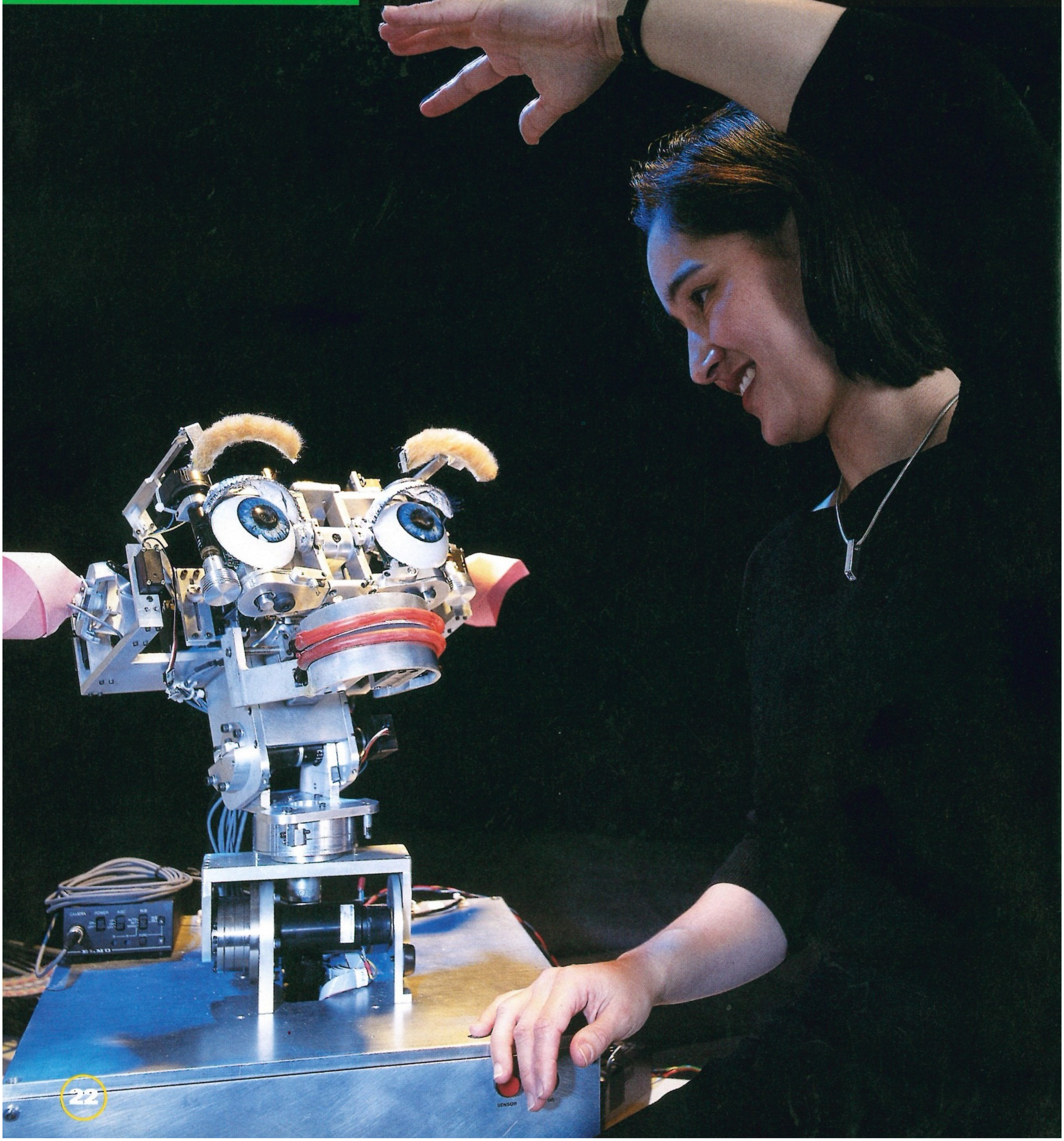
Did you ever wonder . . .

. . . what the difference is between short-term and long-term memory?

Basically, short-term memories are erased quickly. Looking up a phone number usually involves short-term memory. You can remember the number long enough to dial it, and then you forget it. That is unless you're looking up the phone number to the pizza place. Then you have reason to use the number over and over again. Over time, the number gets processed in your brain and it turns into a long-term memory.



Chapter 3 Mechanical Minds



You enter a room and someone calls your name, looks you in the eye, and then invites you to come closer. Right away you decide your new friend, Kismet, is really nice. It's hard to believe Kismet is a robot!

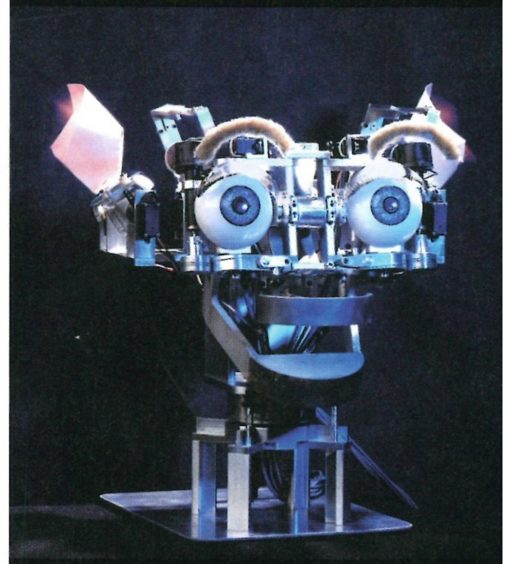
Kismet is a project at the artificial intelligence lab at Massachusetts Institute of Technology (MIT). The scientists running the Sociable Machines Project at MIT have some strong feelings about robots. They don't want to make machines that only perform simple tasks. They want to design robots that can interact and cooperate with people. They want to make robots that can show "feelings" and can play an active part in our daily lives.

Kismet is programmed to pick up on social cues to deliver responses that are very human-like. For example, in a conversation Kismet seems to know just when to speak and when to listen. How does it "know" when to speak up?

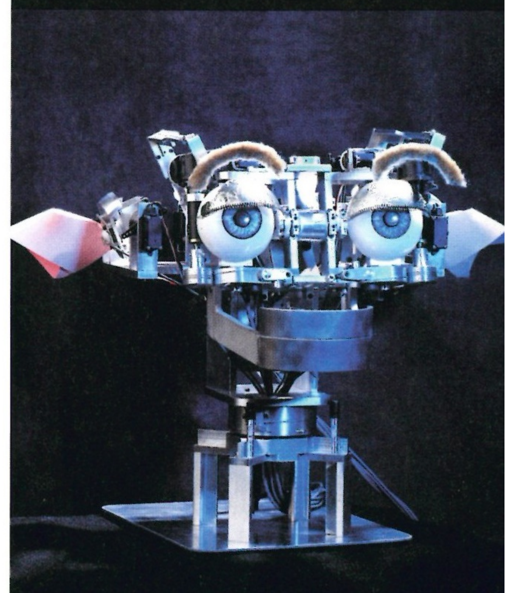
Scientists have studied what people do when they talk to each other. From these observations, they know that people often make eye contact and blink several times when they are ready for a response. So they have programmed Kismet to recognize these actions. When Kismet "sees" these cues, it knows it's time to respond.

So does Kismet have a brain? Not really. But will it be possible to mimic the human brain in the future? Perhaps so.

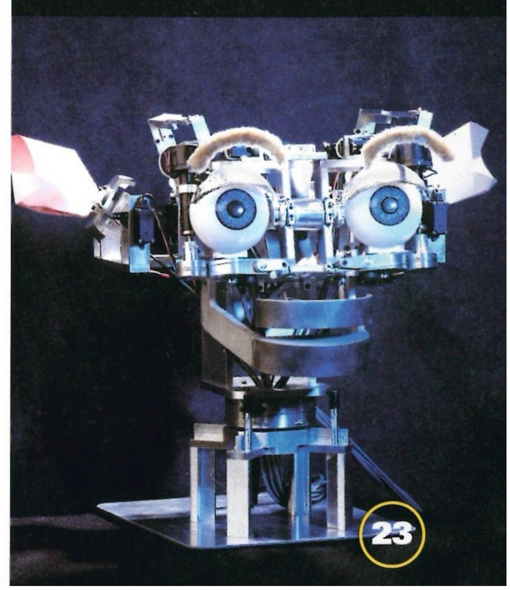
Surprised



Tired



Interested



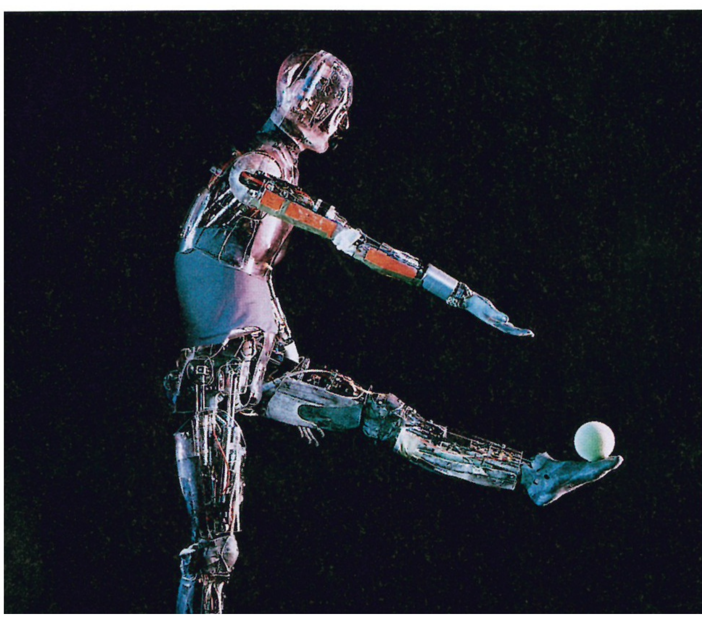
Some robots, like the mechanical cat below, are designed to respond to words.

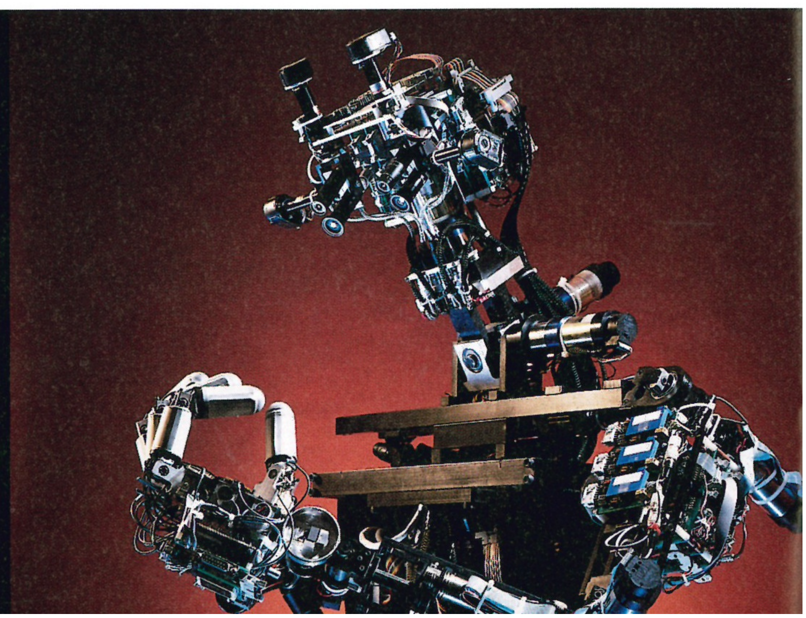
MANNY (below left) is used to test protective gear, such as space suits. COG (below right) has hearing, visual, and touch systems that allow it to interact with objects and people.

Mind-Boggling Machines

Some of the best brains in science think that someday robots might have brains that work as well as human brains. Right now the intelligence of robots is very narrow. They can do some things well. In fact, machines can perform some activities, like calculating and storing memories, better than humans. However, machines can't yet do the variety of things that we are able to do with ease. For example, we can play chess, enjoy a game of football, and then cook a great dinner. A machine can't do all that. But machines are getting "smarter." Some of today's robots actually learn and become better at tasks as they practice them over time.

Let's think about the issue the other way around. Instead of trying to add a brain to a machine, what if we added a machine to a human brain? Scientists are now working on electronic devices





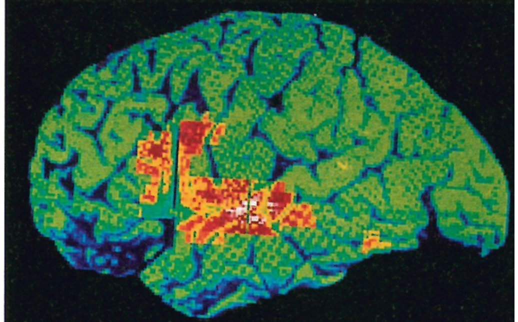
that can replace damaged nerve cells in humans. One such device is already in use. It's called a **cochlear implant**, and its purpose is to replace the damaged nerve cells in a deaf person's ear. Although it doesn't work for everyone, the cochlear implant can send nerve messages about sound to the brain. The implant allows some people to hear again because the brain learns to recognize the signals from the implant.

The Mind at Work

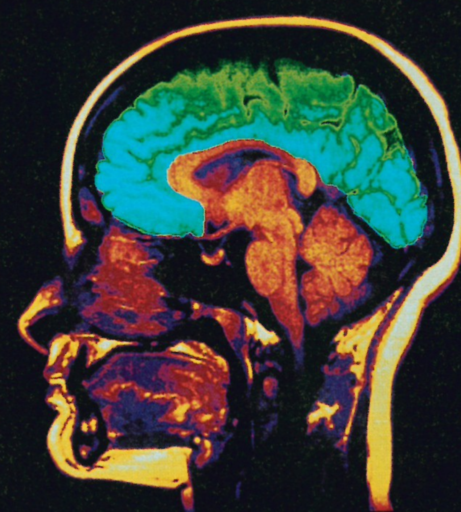
Machines are not only being implanted inside the human head but also are being used to see inside it. How? Well, today doctors can use computer-operated machines to see how a person's brain is functioning. One type of image is called a **PET scan**. It can be used to show the levels of glucose (blood sugar) in the brain. This allows doctors to see which parts of the brain are most active. Other types of images can help doctors see if a patient has a tumor or other irregularity in the brain. One such image is an **MRI**. MRIs show blood vessels, nerves, the brain, and other types of soft tissue. A **CAT scan** also helps doctors find problems in the brain by combining x-rays and computer images to show a cross section of the brain.

The next few decades promise to be even more exciting as new secrets of the brain are discovered. New ways to learn about the brain are just around the corner. What will we be able to think of next?

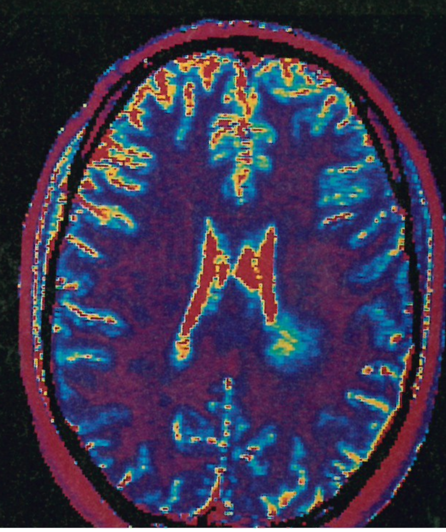
PET scan



MRI



CAT scan



Glossary

axon – the extension of a nerve cell that carries nerve impulses away from the nerve cell body

brain stem – the part of the brain that connects the brain to the spinal cord

CAT scan – a cross-section image of the brain. CAT stands for *computerized axial tomography.*

central nervous system – the brain and the spinal cord

cerebellum (*ser-uh-BEL-uhm*) – the part of the brain that coordinates muscle activity

cerebrum (*suh-REE-bruhm*) – the part of the brain that is involved in thinking and emotions, processing sensory information, and controlling voluntary movement

cochlear implant (*KAH-klee-uhr IM-plant*) – a device that is put into a person's ear that may restore hearing in some people

declarative memory – the type of memory made of facts, figures, names, and events

dendrite – the extension of a nerve cell that carries nerve impulses toward the nerve cell body

infer – to make a conclusion based on your observations and past experiences

memory – the brain's processes of storing learning experiences

MRI – an image that shows soft tissue, such as blood vessels and the brain. MRI stands for *magnetic resonance imaging.*

myelin sheath (*MI-uh-lin SHEETH*) – the layer of fat covering an axon

nerve impulse – the tiny pulse of electricity that neurons send and pass to one another

nervous system – the body's communication network made of the central and peripheral nervous systems

neuron – a nerve cell

peripheral nervous system – the nerves that branch out from the spinal cord to different parts of the body

PET scan – an image that shows levels of glucose (blood sugar) in the brain. PET stands for *positron emission tomography.*

procedural memory – the type of memory that is made of actions, habits, or skills learned by repetition

sensory receptor – a specialized cell that gathers information about what is happening inside your body or what is happening outside your body

stimulus – something that causes you to react

synapse – the space between neurons

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