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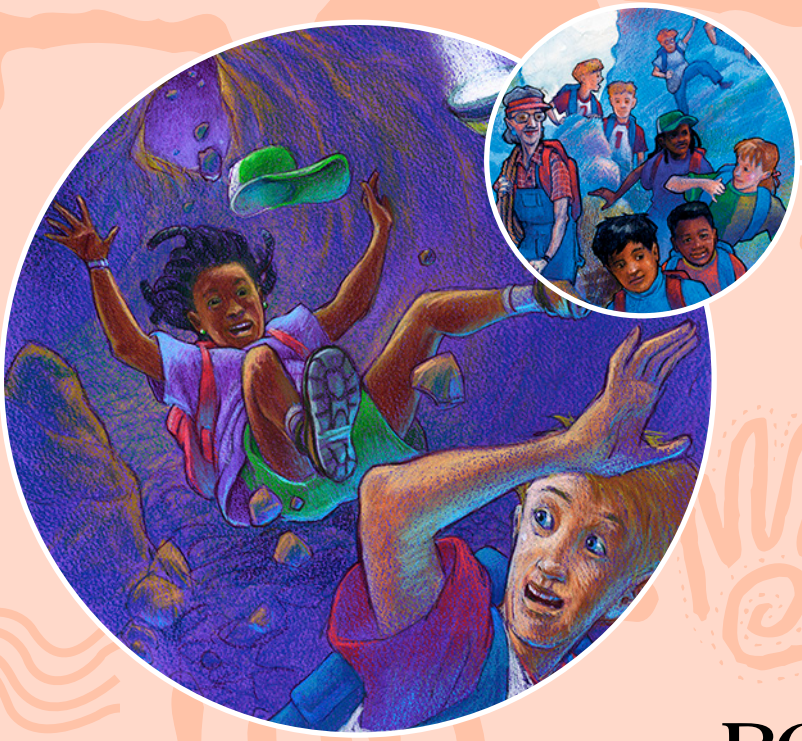
THE LEARNING BRAIN

LEGACY OF LOST CANYON

A Curious Cave Conundrum



Barbara Tharp, Paula Cutler, James Denk and Nancy Moreno

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Legacy of Lost Canyon

A Curious Cave Conundrum

Written by Barbara Tharp, Paula Cutler, James Denk and Nancy Moreno

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NIH Blueprint for Neuroscience Research

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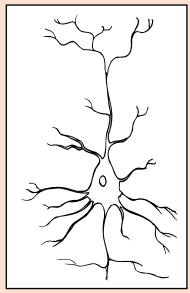
Contents

How the Club Began . . .

All Josh Kavil saw was the stop sign. The next thing he remembered was waking up in the hospital. He had been riding his bicycle without a helmet and was struck by a car. His skull was fractured, and his brain was badly damaged.

Some good came of Josh's unfortunate accident. Once he recovered, he remembered never to ride without a helmet. His misfortune also was the beginning of the NeuroExplorers.

Neuroscientists study the brain and the rest of the nervous system.



The basic building block of the nervous system is the nerve cell, or neuron.

The word "neuron" comes from the Greek word for "nerve."

When Josh's friends came to visit him at Worthington Regional Hospital, some of them became fascinated with the field of neuroscience. During their visits, they met a neurosurgeon, a neurosurgical nurse, a neurologist and a neuroradiologist. These medical specialists help patients who have problems involving the brain or other parts of the nervous system.

It was Kyle Camacho's idea to form the club. The members wanted to know more about the nervous system. They also liked to solve puzzles and riddles, and had an interest in investigating some of the mysteries of science.

Since they formed the club, the NeuroExplorers have volunteered at a rehabilitation center for brain injury patients, held a Neuroscience Fair at their school and spent a day in the hospital participating in rounds with a neurologist. They have learned a lot about how the brain and nervous system work, and they always are looking for exciting things to do with neuroscience.

The NeuroExplorers

B.J. Armstrong

B.J. spends a lot of time with her drums. In fact, she carries her drumsticks with her and uses them on any hard surface she can find! She wants to play in a band, but she also wants to be a physician. B.J. has two older brothers who sometimes act as advisors to the NeuroExplorers. One brother is a neurologist at a medical school. Her brothers never liked to use her formal name, Beverly Jane, so they always call her B.J., and so do her friends.

Kyle Camacho

Kyle's father is an archaeologist at Dargate University and often is away on digs. Last year, he took Kyle with him on a short dig in Belize. Kelly, Kyle's sister, sometimes does things with the NeuroExplorers, although some of the members think she is a little young for the club. Kyle likes to read science fiction books and play computer games. His hobby is memorizing fascinating trivia.

Lakeisha Crawford

Lakeisha wants to be a chess grandmaster, so she carries a pocket chess game around with her. She often thinks about things in terms of chess problems, and she has developed a good memory. She also likes to play other games and sports. Karate lessons are her latest passion. Lakeisha's little sister has epilepsy.

Isley I and Isley II

Identical twins, Isley I and II (even their parents don't call them by their actual first names) are always kidding each other. They both love sports and play soccer, baseball and basketball. Isley I collects baseball cards and has a 1954 Mickey Mantle in good condition. Isley II holds the record for consecutive basketball free throws in his school. Their father, a bird-watcher, got them interested in science by reading to them from the notes of Charles Darwin.

Josh Kavil

When Josh recovered from the head injuries he received in a bicycle accident, he couldn't wait to join the club with his friends. Josh has always liked science, because he loves to figure out how things work. He also loves animals. He has a pet lizard named Scooter, a snake named Slim, two dogs and two cats. After his experience as a patient in a rehabilitation center, he decided he would like to be a physical therapist when he grows up.

Max Miller

Max has been friends with The Brain since they were babies, and that's why he understands him so well. They spend most of their time together. While The Brain reads, Max often works on models of boats and planes or builds things with wood. Max became interested in neurology when his grandfather started having trouble with his memory and was diagnosed with Alzheimer's disease.

Shiloh Nimbus

Shiloh lived on a game reserve in Africa for many years. While there, her back was injured, and now she must use a wheelchair. Before her injury, Shiloh was very athletic. Now she has become an excellent wheelchair tennis player. She also likes to put together jigsaw puzzles with thousands of pieces. Shiloh was happy to make friends with the NeuroExplorers when she came to her new school in America.

Antonio "The Brain" Velasquez-Ruíz

When Antonio Velasquez-Ruíz, alias The Brain, was a toddler, he was very quiet and never tried to talk. One day he suddenly began speaking in complete sentences. Since then, he has been known as the smartest boy in town. The trouble is, only his best friend can understand The Brain's big words and long sentences. The Brain reads a lot, but his most-used books are a very fat dictionary, a set of encyclopedias, and *Gray's Anatomy* (of the human body).

1. History Lesson

Squiggles, stars and arrows—who was copying whom? As Lakeisha, one of the NeuroExplorers, looked from book to book and site to site, she could tell something strange was going on. The picture in her history book was of a famous, 4,000-year-old cave drawing in France, and she knew she had seen a similar picture in her art book, but that image was from Tanzania. While searching the Internet, she had found more cave paintings—or pictographs, as archaeologists call them—in Texas, and the similarities were amazing. France, Tanzania and Texas?

Early cave-dwelling people, thousands of miles apart, and in different centuries, seemed to be telling the same story! Lakeisha had to share this confounding puzzle with her friends.

Her opportunity came during the after-school session of the NeuroExplorers' science club. Over the last three years, the club had had some exciting adventures. It was time for another! Mr. Lopez, the club sponsor, started the meeting by asking the members for ideas for the summer's investigation. He reminded the NeuroExplorers that this would be the last meeting of the school year. Lakeisha immediately spoke up.

She explained her confusion. "How can this be?" she asked as she began to pull out pictures. Her friends all gathered around to have a look. B.J., her best friend, immediately saw a pattern.

"Look at the geometry," said B.J. "The shapes have a definite similarity. Most of the lines are parallel. And . . ."

Isley I and Isley II, twin sports fiends, took one look at the pictures and complained that they'd much rather study the physics of basketball, adding that these drawings were just old artwork, not science.

"On the contrary," spoke up Antonio, also known as "The Brain," "this is a fascinating conundrum of a scientific ilk. Archaeologists study the renderings of ancient indigenous people to derive vital cultural clues."

"He's saying," his best friend and interpreter, Max, interjected, "that this actually is an interesting question. Scientists who study remains of past cultures learn a lot about earlier times from the artwork the people left behind."

"But what's so important about a bunch of old squiggles on a cave wall?" asked Josh.

"That's the whole point," insisted Lakeisha. "I want to know what these drawings mean."

Mr. Lopez interrupted, "I think Lakeisha's question merits some thought."

"Terrific!" groaned Isley I, with a definite attitude. "Now all we have to do is get to France, Tanzania or Texas."

"You know," continued Mr. Lopez, "I haven't thought about this in years, but there's a good possibility of investigating an archaeological site right here in our own backyard, especially since the dam on Rocky River, just above town, curiously ruptured this spring."

"Yeah, I heard the dam was supposed to last forever and it barely made it forty years," said B.J. "Of course, that seems pretty old to me, but what do you mean, 'curiously'?"

"And what do you mean, archaeological site?" asked Josh. "I've never heard about that kind of research in this area."

"Scientists investigated after the dam broke. They found it could have been damaged intentionally, but nothing ever came of their report," explained Mr. Lopez. "In fact, it seemed to be hushed up quickly . . ."

"But I digress." he went on. "What you all need is a little history lesson!"

"First geography and now history. What's next? English?" said Isley I with a frown.

Mr. Lopez ignored Isley I and explained that before Coslett Dam was built, there were limited excavations of caves that pockmarked the canyon walls on either side of Rocky River. Archaeologists from nearby Dargate University were dismayed when the state water commission decided to

locate their next watershed project in an area that would quickly flood access to this research site. Despite protests from the University, Coslett Dam was built. Access to the archaeologists' project was flooded by millions of gallons of water.

"But since the high water is gone after the dam break," said B.J., Lakeisha's co-conspirator, "the entrance to that site might be open again. Let's go!"

"Hold on," Mr. Lopez cautioned. "There's a lot to consider." He reminded the NeuroExplorers that the caves had been unreachable for over forty years.

"However," he added, "I seem to recall that one of the lead scientists on the research team wrote several articles about the site. Her name is Professor Sally Hazelton, I think. Why don't you students do a little investigation and gather some background information?"

2. Walking in Footsteps

Ms. Kay Ching, the librarian, looked up from her desk and found eight pairs of eyes peering intently at her. After hearing the NeuroExplorers' request, she answered, "Yes, I have heard about Dr. Hazelton, but it was a long time ago. What do you need to know?"

"We need to know everything about the university research site by Coslett Dam," said Lakeisha. "On the Internet, we found Dr. Hazelton's e-mail address and references to articles about her team's preliminary findings, but we need the articles themselves. We want to read them before we write to her."

Ms. Ching searched the archives and returned a few minutes later with two old, bound volumes of archaeology magazines and some microfiches containing relevant newspaper articles. She gingerly handed these materials to the group, cautioning them to use care as they examined the materials, and to return them before leaving the library.

Kyle slowly opened the front cover of one magazine as the others looked on curiously. The first article in it was entitled:

> *Early Indigenous Peoples of Rocky River: Preliminary Studies, 1969–1970*
> by Sally Hazelton, Ph.D.

Bingo! The NeuroExplorers all crowded closer as they began to read. Dr. Hazelton's sketches and descriptions of her discoveries were mesmerizing. The silence was intense.

Max leaned in to get a better view as Kyle slowly turned the pages.

Sketches of animals, jewelry, bones, tools and pottery astounded the NeuroExplorers. One drawing in particular caught their attention.

Lakeisha gasped, "*Look!* These are the same shapes—squiggles, stars, lines and arrows—that I showed you on the other cave paintings!"

"Consider the abstruse patterns, the intricate, undulating lines, the convoluted, yet strangely harmonious depictions of these pictographs," murmured The Brain.

Without hesitation, Max came to the rescue. "The Brain is saying that these cave drawings have unusual patterns and a complex arrangement of wavy lines and irregular shapes that seem to have a purpose."

"That's interesting," said Josh, "but I'm still trying to figure out what these weird pictures could possibly mean. What do you guys think?"

Lakeisha said, "I'm not sure, but right below the sketch Dr. Hazelton wrote 'Shaman hunting magic.' We have so much to find out! Like, what's a shaman?"

At this point, the NeuroExplorers divided up the materials and read voraciously to find some answers until Ms. Ching told them the library was closing. After reluctantly returning the materials, they all began speaking at once, trying to share what each had learned or what they thought it all meant.

"Wait!" said Kyle, frustrated. "One at a time!"

Lakeisha began, "Shaman is one name for the spiritual leader in a community. Spiritual leaders had many responsibilities, which could include healing the sick, communicating with the spirits who they believed ruled their world, and escorting the dead to the after-life. Spiritual leaders or healers have been important in many cultures."

"According to Dr. Hazelton's article," added Max, "there are remnants of that past right here in our midst. She discovered the remains of a civilization that was very, very old!"

B.J. chimed in, "Wow, I feel like we've been walking in her footsteps today! We have to meet her."

3. Overload

"What a stroke of fortune," said the e-mail response from Dr. Hazelton. "I have been planning a trip back to my first research site ever since I heard about Coslett Dam's collapse. I would be delighted to meet with your team on my arrival back in River City! I'll meet you in front of the University Library at 3:00 p.m., one week from today."

The group gazed at the message printed from Mr. Lopez's computer one more time while they waited in front of the library. As the giant clock on the science building struck 3:00, up strode a petite, grandmotherly-looking woman in overalls and running shoes. The NeuroExplorers were surprised. The Professor didn't look like the bookish scientist they had expected! This was Dr. Sally Hazelton?

Soon they were deep in discussion. The students had so many questions and Dr. Hazelton had so many answers. But where to begin? They all sat on the edges of their chairs in the library conference room, fascinated by the spunky, quick-witted Professor. They quickly discovered that she was not only an archaeologist, but also an accomplished spelunker *and* a former champion rodeo roper. What an adventure this could be!

After listening to all their eager questions, Dr. Hazelton smiled and said, "It's always best to start at the beginning."

Thus began the engaging story of how this scientist became involved in archaeology and, more specifically, the discovery and investigation of the fascinating dwellings in her hometown. Dr. Hazelton explained that as a child, she had played along the banks of Rocky River, where she found and collected all kinds of interesting bits and pieces that caught her eye.

She later learned that her finds could be important relics, but she couldn't uncover any other information about them.

Intrigued by the little bit she had learned, Dr. Hazelton studied archaeology in college, where she continued to wonder about her discoveries around Rocky River. Finally, after completing several digs elsewhere, she received funding from the North American Heritage Society to conduct her own investigations.

In 1969, she and her team of scientists began work in an area where the river's high canyon walls were riddled with what looked like ancient cave dwellings. They started their excavation of a ten-foot-deep midden in a lower level cave. There, they unearthed several ancient items that provided clues about people who had lived there a long time ago.

At this point, Isley I interrupted Dr. Hazelton. He asked, "What's a midden? What did you find? Where is the stuff? My brain is on overload!" he groaned.

As the rest of the NeuroExplorers glared at Isley I, his twin brother teasingly said, "And what part of your pea-brain would that be . . . Your cerebellum, cerebrum or brainstem?"

Dr. Hazelton curtailed the banter by responding patiently, "A midden is a garbage dump, so to speak. It's where the people living in the caves would have placed their refuse. Among our finds were pottery shards, tools and animal bones."

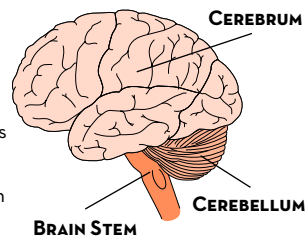
Then she resumed her story. The archaeological team knew that where there was a midden, there would be dwelling areas. Her associate,

The brain is the most complex organ in the body. It is responsible for emotions, thoughts, memory, movement, the senses and automatic functions, such as breathing. The brain communicates with the body through the spinal cord, which connects with a network of nerve cells throughout the body. The brain has three main parts.

1) **Cerebrum** - Responsible for thinking, learning, remembering, senses, emotions and movement that you think about.

2) **Cerebellum** - Helps muscles work together and stores programs for well-learned movements (like riding a bicycle or playing the piano).

3) **Brainstem** - Governs automatic functions such as breathing and heart rate.



Dr. Edwin Morales, found another shallow cave above the initial site. The new cave was particularly exciting because it had mysterious drawings on its walls.

Then, just about the time they were ready to move to this new cave, Coslett Dam was completed. Rocky River backed up into the canyon, and the rising water made it impossible to continue the excavation. Within days, the lower site flooded and the water continued to rise in the canyon. The scientists had argued with the authorities for more than a year to stop the dam project, but despite evidence of the historical significance of their work, the state water commission proceeded with the construction, and access to the second cave was eliminated.

Now that the dam was gone, Dr. Hazelton was eager to resume their work, even though Dr. Morales was in Alaska, conducting scientific research on another site. After she finished her story, the NeuroExplorers began talking all at once. Dr. Hazelton's enthusiasm and energy were contagious. Without exception, the friends felt a rapport with her and were inspired to join her quest. She welcomed their assistance for the summer months. She already had spoken with Mr. Lopez, who told her of their interest and the success of their previous adventures.

4. The Trail

The NeuroExplorers were keenly excited about visiting Dr. Hazelton's research site and about using the training from the camping and trekking classes they had taken earlier in the year. As they assembled to begin their hike, Professor Hazelton, whom the students dubbed "Dr. H.," called for a gear check. Each student was equipped with a day-pack holding food, water, a heavy-duty flashlight and a climbing rope. Kyle also carried a small first-aid kit in his pack.

The group studied the surrounding area. The rocky terrain looked like a strange world. The trail they were following began to slope downward as they approached a canyon cut deep into the Earth. A small river flowed through the base of the canyon.

"Hiking in the canyon will be a little tricky," Dr. Hazelton cautioned. "Remember the plan we went over last night. As the trail gets steeper, walk carefully and stay with your buddy."

The NeuroExplorers already had paired off as partners for this adventure: Max with The Brain, Lakeisha with B.J., Isley I with Isley II, and Josh with Kyle.

Carefully, they began their descent into the canyon. They traveled single file as the winding trail led them past huge rocks along the steep wall down toward the river.

"Did it occur to anyone else that we're just like a string of neurons working together here?" Josh asked as he followed Kyle.

"Astute observation!" The Brain replied, slightly out of breath. "How gratifying that you ponder neuroscientific principles in these potentially precarious environs."

"Nice going, Josh," Max said. "You've impressed him, thinking about neuroscience in such a dangerous place."

The path narrowed as it turned upward. It led the group onto a ledge in the middle of the canyon wall. Then, it ended abruptly. Ahead, a huge boulder blocked the path. On one side of the boulder, the rugged canyon loomed above; on the other side, there was nothing but a steep drop to the river.

Max and The Brain approached the huge boulder, looking for a way to bypass it. "Look up! It appears perpendicular—to wit, quite a vertiginous escarpment," the Brain mused, rubbing his chin in thought.

"*What?*" chorused several of the NeuroExplorers.

"He says the cave opening is straight up from here, and it looks pretty impossible," Max explained. "I guess we'll have to find another way. There's no more trail here."

"Oh, we can go on," Dr. Hazelton assured them. "We can climb up to other natural ledges in the canyon using toe-holes in the limestone walls. See the small cracks and depressions in the wall?"

Suddenly, Isley II said anxiously, "My brother's gone! I think he slipped through this tall crack!"

He yelled into the narrow opening, "Isley, Come back here!" "I'll be right back," he said, as he carefully squeezed through the opening. Once through, he spotted an upward path and followed it for a short way. Then he spotted his brother.

"I was going to come back and get you," said Isley I, turning towards Isley II. "I think I found a short-cut to the cave!"

"You know we're supposed to stay together!" chided his brother. "No more of this disappearing routine or you'll be out of here." Hearing a noise, they both turned in surprise as the rest of the group suddenly appeared from another direction.

"How did you get here?" Isley II asked in amazement.

"We climbed up the wall . . . ," Josh replied, pointing toward the canyon, " . . . then found this path. Dr. H. led us here."

The narrow, winding path led the group further up from the river to one of the canyon's many small caves. From there, the trail continued along a steep ledge.

The walk was often treacherous, yet beautiful. As they made their way up toward Dr. Hazelton's first excavation site, the group peered up and down the canyon walls. The view was breathtaking. Far below, they could see huge boulders stacked at the edge of the river like stepping stones for a giant. They were enormous, yet perfectly stacked in the strangest of ways. Nature's balance was on display! The group had hiked into the canyon and now was up on its walls, already high above the river.

As everyone crept along the precarious ledge, Dr. Hazelton cautioned from the lead position, "Be careful! Hold onto the rock. There's water coming from somewhere above and the ledge is as slippery as slime."

Each NeuroExplorer, in turn, passed the message on down the line. But before the message got to Kyle, a panicked shriek echoed off the canyon walls. He had slipped on the wet ledge and was sliding fast! Josh instinctively grabbed Kyle's shirt and the quick-thinking NeuroExplorers immediately joined hands to form a human chain to pull Kyle back up onto the ledge.

"Critical, timely firing of our synapses has forestalled a calamity!" The Brain said loudly.

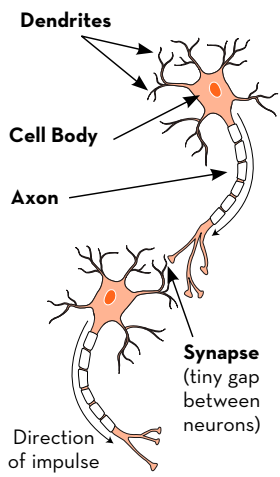
"He says that our quick thinking and action prevented a terrible accident," Max translated for the others, who looked at The Brain

The brain communicates with the rest of the body through the spinal cord and a network of neurons.

Neurons are specialized cells that send messages in one direction. They receive messages on branches called dendrites. The messages are carried along the cell membrane and through the axon as an electrical charge. Messages are passed to the next neuron by special chemicals called neurotransmitters.

Neurotransmitters move across the synapse (tiny gap) between cells and attach to special receptors in the next neuron. Each neurotransmitter has its own kind of receptor. They fit together like a key in a lock.

Different neurotransmitters can act together to signal neurons to send messages (called firing) or they can keep neurons from firing.



Hormones have vital functions in mammals. They circulate in the bloodstream and act as chemical messengers to the nervous system and to other parts of the body. Unlike neurotransmitters between neurons, hormones can have wide-reaching effects on many different tissues in the body at the same time. However, hormones can act only on cells that have the right kind of receptors.

In times of danger, a number of nonessential bodily functions, such as digestion, are shut down. Other systems are "revved up" in anticipation of needing to fight an enemy or to run away. This reaction is partially controlled by the hormone adrenaline (epinephrine). You may have felt its effects at one time or another. They include a pounding heart, sweaty palms and a feeling of nervousness.

with annoyance. Then they looked at Kyle, who was safe, but visibly shaken.

"*Wow!* You saved my life!" said Kyle with a sigh of relief and disbelief. He sat on the ledge, catching his breath. "Whoa! My heart is really pounding!"

"My heart is pounding hard, too!" Josh answered. "That adrenaline sure kicks in when the going gets rough, doesn't it?"

5. Discovery

"That was too close for comfort," Dr. Hazelton said firmly. "Watch your step. We're almost to the first cave I explored. Let's get there and break for lunch."

B.J., ever the drummer, slapped a drum roll with the palms of her hands on the rock wall in agreement, as the athletic Isley twins high-fived. Next to a good mystery, food was their favorite thing! They all carefully continued up the path, toward the cave.

When they reached their destination, Lakeisha remarked, "This place is gorgeous, but what a trip! Do you really think people lived here thousands of years ago? It seems impossible."

The Brain replied, "There is a preponderance of evidence to suggest that an indigenous population existed in these spectacular, albeit inhospitable, environs, Lakeisha."

"*Max!* Translation!" the Isleys demanded simultaneously.

"In brief, The Brain is saying that, according to Dr. H.'s preliminary findings, people actually did live in this dangerous area," Max explained patiently.

"Exactly," agreed Dr. Hazelton. "My research in Lost Canyon was just beginning to show not only that people of an early civilization inhabited

The brain and nervous system need many different kinds of raw materials to carry out activities within cells and to manufacture the messengers that communicate between neurons.

A diet that includes enough energy sources from whole grain breads and cereals; plenty of fruits, vegetables, lean meats or other protein sources; and low-fat dairy products provides everything the brain needs to perform at its best.

these caves, but also how they lived." As she bent to examine something, she exclaimed, "And here could be more proof!"

"What is it?" the NeuroExplorers cried in unison while crowding around Professor Hazelton.

"I can't tell for sure without excavating it completely, but it looks like a . . . ." Professor Hazelton's voice trailed off as she carefully unearthed a small tool.

Kyle spoke up. "It's a pickax—one like my Dad uses in his archaeological digs."

"Yes," said Dr. Hazelton. "It may be one we unintentionally left behind. My crew and I had to abandon the cave abruptly when they began dynamiting for the dam."

Dr. Hazelton began to study the site. All the memories she had about the cave came flooding back. As the NeuroExplorers hungrily devoured their lunches, they watched with interest when she moved to inspect the cave's floor and then its walls with cat-like curiosity. As she walked, she explained that only the initial stages of cave exploration had been completed.

"Almost from the start, this cave was a treasure trove for lots of reasons. Hmmm. This looks familiar. Let's see . . ." she whispered, almost to herself, as she moved closer to the cave's back wall.

"Where *are* they?" she suddenly asked. "I *know* this is where I found the cave drawings."

As the light from her flashlight moved upward, it revealed several dark patches on the wall. A look of horror crossed her face. "Oh, no," she gasped. *"The drawings have been cut out of the wall!"*

"You mean the cave drawings in your book?" asked B.J. "The ones that have the squiggles and stuff?"

"Yes. They're *gone!"* Dr. Hazelton cried as she frantically flashed her light over the wall. "Such beautiful pictographs. Who would have done this? Who *could* have done this?"

The NeuroExplorers stood up and stared at a scarred rock wall. Large rectangles were gouged out of the surface. It was a devastating sight. Only a few remnants of painted figures remained intact. No one dared move or turn on a flashlight or say a word. They just watched as

Professor Hazelton stood stone still, in near shock, in front of the scarred rock wall.

In only a few hours, they had found what had been inaccessible to the Professor for thirty years. She had led them almost directly to the spot, even though much had changed in the canyon due to erosion from years of rushing water and floods. It seemed inconceivable to them that Dr. Hazelton's amazing discovery had been permanently removed.

6. A Secret Cave

All at once, the stunned group heard strange, indistinguishable sounds echoing through the cave. The sounds started slowly and faintly, became urgent, then stopped.

They looked at each other. What? . . . Someone or something else was in the cave! Then another muffled echo broke the silence. Taking mental count, they simultaneously realized that Isley I was missing. Once again, he had slipped away. Perhaps the sound was Isley calling out.

"*Isley,* this isn't the time for one of your pranks," yelled his twin brother and hiking partner. "Where *are* you?"

There was no answer. The sounds had ceased. In the quiet, a high-pitched pinging sound rang out. But that sound was coming from another direction. The cave echoes increased their confusion!

"Isley, I'm not kidding! Where are you?" yelled Isley II.

Professor Hazelton turned her attention from the scarred wall and calmly said, "Let's not panic. We can find him. I know there's only one way into this cave and he has to be around here somewhere!"

Professor Hazelton called out for Isley I, but there was no answer, only her voice falling off in echoes through the cave. They all grew deadly quiet, straining to hear through the silence. After what seemed like an eternity, they heard what had to be his voice, coming from far away. At the same time, the pinging noises began again.

Finally, they recognized the low, distorted voice and words of Isley I. "I'm down here . . . Guys! I'm down here . . . ."

Everyone began looking frantically about the cave, but there was no "down here," just a rock-strewn dirt floor that went all the way to the

back of the cave. With flashlights illuminating their way, the group spread out. They searched up and down the walls and around the edges. Though they heard Isley I calling, they still could not see him.

Finally, near the very edge of the cave's sloping back wall, Lakeisha discovered a small depression in the floor near several large rocks. It looked as if the earth had pulled away from the wall, leaving an opening not much larger than a backpack—possibly just large enough for one Isley to slip through.

Lakeisha dropped to her knees, put her head near the opening and hollered, "*Hey Isley!* Are you down there?"

"Yes, I'm down here." he grumbled back.

"What are you doing down there?" laughed Lakeisha, glad to have found him. "Are you okay?" she asked, as she turned to stand and alert the others.

"Yes. But be careful up there, Lakeisha. The edges of the hole crumble easily," Isley I said, as a couple of pebbles landed nearby.

Without warning, Lakeisha suddenly slipped feet first through the hole and landed right on top of Isley I! "What a ride," she sputtered in surprise, as she pulled herself up and off of Isley I.

"Hey, I broke your landing, didn't I, so what's the problem?" grinned Isley I. He added, "I stepped onto a big rock close to the wall up there to get a better view of the damage. The rock wobbled a little and the floor beneath it collapsed. I slid down here just like you. What a *fantastic* rock slide!"

"It *was* quite a ride—but I don't think we can repeat it in reverse. It's too steep of a climb," replied Lakeisha. "Now, what?"

They looked at each other, then both began to call, "Help! We're down here!"

Across the cave, Professor Hazelton faintly heard the two of them yelling. She followed the direction of their voices, but though the cries became louder, she still couldn't see anyone. The Professor waved her light up and down across the area and finally caught sight of the depression in the cave floor.

Bracketing the opening with her feet, she directed the light down into the hole. She could see Isley I and Lakeisha. They both seemed to be

okay, standing in what looked like another cave. She hesitated; as far as she knew, these caves did not have anterooms, or connected chambers, deeper into the walls of the canyon. Nevertheless, Isley I and Lakeisha appeared to be in a connecting room of the cave!

While Isley I and Lakeisha waited for the others to rescue them, they could only wonder about where they were. It was almost completely dark, and both of them had lost their flashlights when they fell through the opening. But the air was surprisingly fresh and they could feel the smooth, cool floor beneath their feet. A tiny ray of sunlight from somewhere up above allowed them just barely to see each other. Slowly, as their eyes became accustomed to the dark, they could see some faint outlines on the wall closest to them. The lines looked like a jumble of frenetic shapes.

As the Professor called down to them, the others arrived on the spot. Dr. Hazelton quickly explained what must have happened as she anchored Isley II's rope in the cave wall and began lowering the rope into the cave for their descent.

7. Supernatural Moment

Dr. Hazelton was the first to climb down the rope to Isley I and Lakeisha. One by one, the other six NeuroExplorers followed. Soon Kyle was waving his flashlight around in the new surroundings.

"This is a pretty big cavern," he observed. "I'll bet someone used it long ago. It would be a neat place to hide out." He moved further into the cave with Josh.

"Well, leave it to my brother!" said Isley II, grinning at Isley I. "Maybe we should call you a CaveExplorer instead of NeuroExplorer!"

Once the initial commotion ended, Professor Hazelton asked the group to sit down for a minute in order to take stock of their situation. She wasn't angry with Isley I for causing concern. After all, it had been an accident, not a prank. In fact, she was excited that Isley I and Lakeisha had discovered another chamber for her to explore. And this chamber was big, *really* big! The room picked up every word, sending voices ricocheting back and forth.

"Well, what do you think this place is all about?" she asked leadingly.

As usual, everyone began to talk at once. All the words formed a disjointed, cacophonous echo that bounced around the room and could not be understood.

The NeuroExplorers were full of questions, but no one could be heard over the others. "What are . . . I think . . . Who is . . . Where . . . How . . . ?"

With a sharp whistle, Dr. Hazelton brought them all back to attention. She moved to the center of their circle. Everyone watched silently as she lifted her light high and slowly turned around the room. They were

totally awed, left speechless by the intricate ancient images that surrounded them. Everything they had read and everything the Professor had discussed was now encircling them. The cave was enormous—over fifty feet across. But just as in Lakeisha's pictures, the untouched pictographs told a story.

It was an almost supernatural moment. The colors, the shapes, and the mysterious aura that surrounded them spoke of a different world. It was a history book without words!

Paintings covered every wall. Professor Hazelton seemed to be studying one in particular. She asked all the NeuroExplorers to shine their lights on the same wall. Their lights illuminated a huge mural. It was as big as a billboard! The wall painting featured six human-like figures linked by some sort of rope, along with a variety of animals, arrows, squiggly lines and dots.

"Pictographs—rock paintings crafted by inhabitants of this canyon!" exclaimed The Brain in obvious appreciation.

"Look at those crazy lines and wild pictures. I wonder what they could mean?" commented Max.

The Brain contorted his face in deep thought. "I fear none but Dr. H. is qualified to decipher these enigmatic creations. However, I posit this ancient rampart is a priceless galley."

Max said, "The Brain thinks Dr. H. is the only one who can explain these puzzling drawings, but they're probably very valuable as art."

"You call this art?" replied Isley I, incredulously. "It looks like some kind of strange graffiti to me!"

"On the contrary," disagreed Professor Hazelton. "When a person writes on a wall or structure without permission, it is considered graffiti. Graffiti often is considered destructive. But this is so much more—amazing pictographs!"

8. Hallucinogens

"This truly is a find, a pristine site," declared the Professor. "Do you see that tiny circular hole, way up there in the ceiling? See where the light is coming through? Well, that hole once served as a smoke vent for fires that the healer burned just about where you're sitting right now."

She continued as the NeuroExplorers listened with rapt attention. "Evidence suggests that rock paintings of some ancient peoples were related to the spiritual activities of the community. What these ancient pictographs mean and why they were made is not well understood. We believe that much rock art was inspired by religious beliefs. Also, these paintings often are thought to represent visions induced by hallucinogenic medicines taken by the leaders to carry them to the spirit world."

"Psychotropic substances have been utilized by various cultures throughout the annals of time," murmured The Brain.

The others were too wrapped up in their discovery to ask, but Max translated anyway. "Many different peoples have used mind-altering substances."

Finally, the excited group took a collective deep breath as Dr. Hazelton pulled a lantern from her day-pack and lit it. The room began to glow in a golden light. It was magic! They stood transfixed.

"So many of the shapes are the same as those I've seen in my art book. It's more than amazing," said Lakeisha in whispered respect.

"According to research, these shapes are found in many cave pictographs due to the healers' or spiritual leaders' common experiences. Many cultures believed that to commune with the spirit world, one had to enter a trancelike state. This state of mind often was a reached after

long periods of intense meditation, or after facing a difficult physical challenge, such as going without food or enduring extreme heat or cold. Sometimes, hallucinogenic medicines, or herbs, also were taken. Regardless of the methods used, the effects on the brain apparently were very similar. Quite often, as you now can see for yourself, the geometric shapes, and even the colors, were similar—even in paintings done continents apart."

Isley II was puzzled. "Are you saying they took drugs back then? I thought those were invented in the 1960s."

"Sure they did," said Dr. Hazelton. "Today we hear about drugs like marijuana, LSD and cocaine. Some of these substances may be very much like the ones early people used. Of course, life was very different long ago. Now we know much more about how different chemical substances affect the brain. We're still a long way from understanding them completely, but we *do* know they can be dangerous."

Isley II said, "I take drugs every day . . . for my asthma."

"Yes," agreed Professor Hazelton, "any substance that affects how the body works is a drug. Medical research has found countless good uses of drugs to treat illnesses."

"Like pain relievers," Lakeisha suggested.

"And anesthesia," offered Max.

Many mind-altering drugs abused by children, teenagers and adults lead to permanent changes in the brain and other parts of the body.

- **Marijuana** can damage memory regions of the brain. It also affects coordination and the senses.
- **Heroin** changes the way nerve cells in the brain receive and process messages, and it reduces neuron activity involved in pain and anxiety. At high doses, it can cause drowsiness, reduced breathing and death (from breathing difficulties).
- **Inhalants,** which are absorbed by fatty tissue in the body, can damage the fat-containing insulation (myelin sheath) on nerve cell axons.
- **LSD** contributes to the development of chronic mental disorders. It also causes hallucinations, confusion, anxiety and muscle weakness.
- **Alcohol** damages many organs, including the liver and brain, and is a major contributing factor to automobile accidents.
- **Nicotine,** in tobacco, is very addictive. However, the greatest health risk comes from other chemicals in cigarette and cigar smoke, which are linked to several different kinds of cancers.

"What about drugs doctors don't prescribe, like alcohol and marijuana, and even cigarettes?" B.J. asked. "Lots of people use them, too. How dangerous are they?"

"They can be very harmful," Professor Hazelton replied. "People who choose to use dangerous drugs are risking everything. These days we know drugs affect the brain and can damage the body, sometimes permanently, and we're working to understand more and more exactly how that occurs.

Studies on how chemical messengers work within the brain and nervous system hold promise for unraveling many basic questions about the actions of drugs and the causes of some diseases. Almost all drugs that influence the way the brain works do so by altering the transmission of chemical messages by neurotransmitters. This can have important medical applications for the treatment of severe pain or illnesses, such as schizophrenia or depression.

For example, some medicines used to treat depression act on chemical messengers involved in regulating sleep and body temperature. Morphine, a potent pain medication, mimics the effects of a natural chemical messenger involved in minimizing pain and producing a sense of well-being.

9. Vision Quest

Professor Hazelton resumed her discussion, and the NeuroExplorers gave their complete attention. "In some cultures, a healer's supernatural trip was called a vision quest. It was believed that the ritual would allow him to obtain, and sometimes manipulate, supernatural power."

"After years of training and preparation, a person finally would become a healer by going on his first vision quest, sometimes accompanied by another person and sometimes alone. In either case, he would leave his community and travel to a known vision quest spot—often a petroglyph site like this one, believed to be inhabited by spirits. It might be a distant location or it might be relatively close to his own village, but the quest always would occur when the other members of his community were not around."

"The healer would pray when he arrived at the vision quest site and even might seat himself in front of a chosen rock. He would remain at this spot without food, water or blankets for a number of days, praying and meditating—usually until he had a vision. Sometimes during this period, he also might use some type of drug. Depending on the area, the drugs used could have included potent native tobaccos or peyote. These are strong hallucinogens that brought about visions."

"Some healers' visions were believed to represent an entry into the

There is a difference between drug abuse and drug addiction. Drug abuse is a voluntary activity: a person makes a choice about taking a drug. Drug addiction is a compulsion: the need to use a drug is overwhelming. Eventually, the body becomes "used" to addictive drugs, causing severe withdrawal symptoms when the substance is removed. In the end, addicted people continue drug use to avoid the pain of withdrawal, rather than to derive any pleasure from the experience.

Many chemicals have powerful effects on the nervous system. Some drugs act like chemical messengers (neurotransmitters) between cells. Others interfere with the manufacture or recycling of messengers. Cocaine, for example, interferes with the removal of a neurotransmitter that causes certain neurons in the brain to "fire" (send signals to other neurons).

supernatural world. The images you see on these walls most likely depicted the events and spirits the healer experienced while in this altered state. The painting was greatly influenced by a healer's way of life and personal experience, but because all humans have similar mental systems, some aspects of all visions were the same. The healer left the pictures of his visions on the rocks to preserve his experiences. The designs often were thought to be made at the conclusion of the vision quest."

The NeuroExplorers' intense concentration was broken when they again heard the strange pinging, and now banging sounds, coming from somewhere nearby. The echoes were louder now, cutting through the quiet canyon like a knife!

"Sensory overload," blurted The Brain. "Following such acute cogitation over the Professor's extraordinary account, this clamor is a heavy mallet on my tympanic membrane!" Everyone else covered their ears, too. No translation was necessary this time.

"If that's what I think it is, I have to stop it," said Dr. Hazelton grimly, as she ran over to the rock slide and used the rope to pull herself back up the wall to the chamber above.

"Wait! Where are you going, Dr. H.?" called Kyle. "What's this about?"

"No time to explain," Professor Hazelton called back. "I have to go now!" With that, the agile Professor took off running!

The NeuroExplorers quickly took stock of their improbable situation. Wherever Professor Hazelton was going, they were going too. As one, they ran across the cave toward the dangling rope. As quickly as possible, they took turns pulling themselves up the rope, using their legs and feet to bounce off the sloping rock wall.

"This isn't nearly as easy as Dr. H. made it look," B.J. huffed noisily. "She is amazing—fit *and* fast!"

Once they all were up, they ran through the cave and out to the narrow ledge from where they had entered. Professor Hazelton was nowhere to be seen.

10. Following the Bang

The NeuroExplorers' eyes scanned up and down the canyon walls as they continued to look for the Professor. They saw nothing except boulders and some flood debris on the opposite side of the canyon.

"Quit talking and listen! Those banging sounds have started again and I think they're coming from up there," said Kyle, pointing his finger directly up the sheer rock wall.

"Well, where else could she have gone? Why would Dr. H. leave us?" said Lakeisha, looking around nervously.

"I say we go up," urged Isley II. "She might need our help!"

"Easy for you to say," said B.J. "Just how do you suppose we get up that sheer cliff? We don't have time to anchor our ropes!"

"Like this," answered Josh, as he began the ascent, toe-hold to toe-hold. "It's a piece of cake—follow me!" The rest of the NeuroExplorers were off immediately, snaking their way up the face of the cliff.

After eight challenging toe- and finger-holds, they all reached another natural ledge—but Professor Hazelton was still nowhere to be found. Josh gave them all a hand up onto the ledge, and the NeuroExplorers once again began navigating a narrow precipice over Rocky River, now far, far below. They continued in careful concentration as the trail led steeply up the canyon wall. The banging grew more intense as they made their way around a huge boulder.

Suddenly, the group heard an ear-piercing shout! They almost tripped over one another as they jammed to a quick halt. The trail led directly into another huge cave. Should they enter this deep, dark cave without Professor Hazelton?

"We've come this far. Why stop now?" asked Isley I excitedly. "Besides, it's not very cozy out here on this ledge, either. I say we follow the sounds. That's where we'll find Dr. H."

The NeuroExplorers cautiously entered the cave with flashlights turned on. Three steps in, there was another loud cry.

"I'm not so sure I want to go on with this," whispered Lakeisha. "We really don't know if this is about Dr. H. It sounds like there could be trouble in there."

"There was no other way for her to go. She has to be there—and she needs us," Kyle urged impatiently.

As one unit, they moved silently forward, listening intently for anything that might tell them where to go. But there were no more sounds. Finally, they saw a faint halo of a light and two figures. The NeuroExplorers moved cautiously forward to get a better look.

11. The Culprit

Suddenly, they halted—stunned. Deep in the shadows, tiny Professor Hazelton was tightening the hold on her rope. It was wrapped around a burly man who was struggling wildly to get free.

Lakeisha yelled out, "Dr. H., it's us—are you okay? What's going on?"

"I came up from behind and surprised him," the Professor replied, a bit breathless. "I used my rope to lasso this despicable man. He's the culprit who was hacking out the pictographs. I caught him red-handed! I'm *not* letting him escape either. Come help me!"

The NeuroExplorers charged at the bellowing man on the ground and quickly finished tying him up using their climbing ropes. Then they turned him over.

"Why, it's Jeb Hunnicutt!" exclaimed Professor Hazelton, astounded. "You grew up in these parts, just like me, Jeb. You once were a promising geologist. Just *look* at you now. Erasing history . . . I can't believe it!" She paused for a moment before continuing with a determined look in her eyes. "Well, you won't be destroying any more of these precious pictographs!"

"But why would he even do it?" asked a confused Lakeisha.

"He's the only one to know for sure, but I suspect Jeb has a market for these relics, even if they come in pieces," said Professor Hazelton. "The pinging and banging sounds were made as he chiseled away at the rocks, removing the pictographs, piece by piece, as they broke free from the wall. I'm beginning to think the dam didn't break by accident. From the look of things, Jeb was able to start his thievery suspiciously soon after the water level dropped."

"What do we do with him?" asked Josh.

The group was still in the canyon and needed help getting Jeb out, so Professor Hazelton called the authorities on the cell phone she had stored in her day-pack. Since they were only about forty feet from the top of the canyon, she also sent the Isleys on a scouting trip to find another way out. She couldn't begin to imagine getting Jeb out the way they came in. It was impossible to do so safely unless he was untied—and that simply wasn't an option.

After a few minutes of brainstorming, the group heard a whirling sound outside. The rescue helicopter was overhead and the Isleys were flagging it down!

"They sure got here in a hurry," commented Kyle.

"It's a good thing, too," said the Professor with a slight grin. "The more I think about what Jeb's done, the more I want to leave him tied up in this cave!"

Everyone laughed—except Jeb, who gave Dr. Hazelton an icy stare. Within a few minutes, the flight crew had lifted the small group onto the helicopter and headed back to River City.

Later, the NeuroExplorers reconvened at the library with Professor Hazelton. She thanked them for their quick thinking and hard work. Then, with unmitigated enthusiasm, she declared, "I fully intend to document our findings from the caves and tell everyone about the treasures up in those canyon walls. We're going to get legal protection for the whole canyon, so that this time, we can save those relics. Most important of all, I'm going to include all the NeuroExplorers—my newest and most energetic research collaborators—in future excavation efforts!"

Glossary

addiction (uh-DIK-shun) - a disease characterized by changes in the structure and workings of the brain, caused by prolonged use of habit-forming drugs; addiction involves a compulsive need to use a habit-forming drug, loss of control over the amounts of the drug taken, and an intensive craving for the drug when it is not available.

anatomy (uh-NA-tuh-mee) - the structure (both inside and outside) of a person, plant or animal.

archaeologist (ar-kee-AHL-uh-jist) - a scientist who studies the remains of past human life.

axon (AX-on) - long-tailed branch of a neuron along which signals are transmitted to other cells.

brain (BRAYN) - the control center of the central nervous system, located within the skull and attached to the spinal cord; the command center of the body.

brainstem or brain stem (BRAYN-stem) - structure that connects the rest of the brain to the spinal cord and controls basic survival activities such as breathing, heart rate, body temperature and digestion.

cacophony (kuh-KOF-uh-nee) - many unpleasant sounds occurring together at one time.

cell (SEL) - the smallest unit of life that is capable of functioning on its own, and of which all living things are composed; tiny living unit containing a nucleus and surrounded by a thin layer (membrane).

cerebrum (suh-REE-brum) - the large, domed, top area of the brain where thinking, learning, memory and decision-making occur.

cerebellum (sehr-uh-BEL-um) - part of the brain located directly behind the brainstem; controls the sense of balance and helps the muscles work together for learning and coordination of rote movements.

conundrum (kuh-NUHN-druhm) - a question or problem having only a conjectural answer; an intricate and difficult problem; a riddle.

Darwin, Charles (DAR-win) - a naturalist in the 1800s who studied plants and animals around the world and is known for his book, *On the Origin of Species.*

dendrite (DEN-dryt) - one of many treelike branches extending from the body of a neuron, on which signals are received.

depression (deh-PREH-shun) - a brain disorder characterized by feelings of sadness, despair, hopelessness and low self-esteem, and sometimes accompanied by other symptoms, such as loss of appetite and energy.

disease (diz-EEZ) - sickness; a condition that interferes with the normal function of some part or parts of the body, caused by environmental factors, microbes or inherited conditions.

fiber (FY-ber) - a thread or threadlike part; sometimes used to describe a long axon.

hormone (HOR-mohn) - chemical messenger that circulates in the bloodstream and can affect many different tissues of the body, including the nervous system, at the same time.

impulse (IM-puhls) - the transmission of a signal along a neuron fiber.

indigenous (in-DIDG-in-us) - having originated or been produced in, or growing, living or occurring naturally in a particular location.

midden (MID-in) - archaeological site containing discarded items and materials from an ancient society.

motor neuron (MO-ter NU-rahn) - a type of nervous system cell, originating in the brain or the spinal cord, that sends impulses which cause movement.

navigate (NAV-i-geyt) - to make one's way over or through; traverse.

nerve (NERV) - bundle of neuron fibers.

nervous system (NER-vus SIS-tum) - the brain, spinal cord and network of nerves in the body.

neurologist (nu-RAHL-uh-jist) - a medical doctor who specializes in diagnosing and treating disease and injury in the nervous system.

neurology (nu-RAHL-uh-gee) - branch of medical science that deals with the nervous system.

neuron (NU-rahn) - a cell of the nervous system that conducts a signal from one part of the body to another; nerve cell.

neuroradiologist (nu-ro-ray-dee-AHL-uh-jist) - a medical doctor who uses pictures of the inside of the body (x-rays and others) to identify injury and disease in the nervous system.

neuroscience (nu-ro-SY-ens) - a branch of science related to research on the nervous system.

neurosurgeon (nu-ro-SUR-jun) - a medical doctor who specializes in brain, spinal cord and nerve operations.

neurosurgical nurse (nu-ro-SUR-ji-kul NURS) - part of the team of people who work with a neurosurgeon to perform surgery on the nervous system.

neurotransmitter (nu-ro-TRANS-mit-uhr) - chemical messenger that transmits signals between neurons; neurotransmitters are released from the axon of one neuron, cross the synapse (tiny gap) between neurons, and bind to special receptors on a dendrite or the cell body of a second neuron.

petroglyph (PEH-tro-glif) - a drawing or carving on a rock; rock art.

pictograph (PIK-to-graf) - an ancient drawing or painting on rock; one of the symbols belonging to a story told as pictures.

precipice (PRES-uh-pis) - a very steep or overhanging place.

receptor (ree-SEP-tuhr) - specialized place where a chemical messenger (hormone or neurotransmitter) attaches to a receiving cell; each receptor is shaped to fit a specific chemical messenger.

schizophrenia (skits-uh-FREEN-ee-uh) - severe brain disorder that can make it difficult to know what is real and what is not, and can involve a number of symptoms, such as hallucinations, delusions and withdrawal from other people.

shard (SHARD) - fragment of something brittle, such as pottery.

skull (SKUL) - all the bones of the head, including the cranium and the facial bones.

spelunker (speh-LUN-ker) - one who explores and studies caves.

spinal cord (SPY-nuhl kord) - the thin rope of nervous tissue inside the bones of the spine.

synapse (SIHN-aps) - tiny gap between the axon of one neuron and the dendrite of another neuron, across which messages are transmitted chemically or electrically.

tissue (TIH-shoo) - many cells of the same kind, joined together to do a specific job.

About the Authors

Barbara Tharp, originally from California and Oklahoma, once worked for the FBI in Washington, DC, and later was an economic analyst for an oil company. From there, she followed her primary interest of working with children, serving as an elementary school teacher and specializing in her favorite subjects, science and math. Currently, she serves as a full-time faculty member at BCM. In addition to creating instructional materials, she directs science and math teacher enhancement programs with classroom teachers from Houston and throughout the US.

Paula Cutler, a native Texan, was an educator for more than 20 years, first as a high school English teacher and an elementary school teacher, and later, as an education coordinator at the Houston Museum of Natural Science. While at BCM, she served as project manager and was involved in numerous teacher professional development programs. She especially enjoyed creating instructional materials for, and interfacing with teachers.

James Denk is a professional writer and editor specializing in educational, technical and creative writing. Prior to coming to BCM in 1990, he earned his Masters degree in 17th century British literature at Texas Tech University, where he also taught freshman English composition. As a faculty member at BCM, his work now focuses on developing and editing educational materials, producing extramural grants and contracts, and writing and editing academic articles. In addition, Mr. Denk is a published lyricist and photographer.

Nancy Moreno, originally from Wisconsin and Michigan, is a biologist with a specialization in botany. She studied and classified neotropical plants in Mexico before completing her doctoral degree. Her current interests focus on the involvement of scientists in the education of students and teachers. She designs curricula, conducts teacher workshops on best science teaching practices and the use of technology, and is involved in science education at all levels. Her specific science interests are ecology and environmental science.

The Learning Brain:
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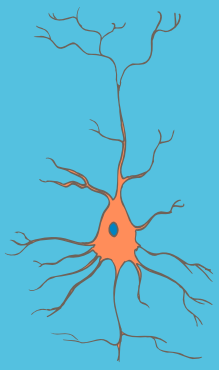

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