Yet More Everyday Science Mysteries

Stories for Inquiry-Based Science Teaching

Richard Konicek-Moran

NSTA press
National Science Teachers Association

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The Stories and Background Materials for Teachers

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Christiana Admiral, Pine Island District Interpreter, Everglades National Park,

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Preface

Teaching and Interpreting Science

Over the past nine years my wife and I have had the privilege of being nature interpreters in the Everglades National Park. We were warned that interpretation was different from teaching. We were not supposed to be lecturing about the names of birds or plants but helping the visitors tune into the beauty and value of the park. In fact, we were told that our major goal was to help the visitors make "an emotional connection to the resource (the park), not to teach."

So, it would seem that teaching and interpreting are quite different entities. I'm not sure I agree, or perhaps it is that I hope that they become more like each other. Synonyms for *interpret* are "enlighten, elucidate, clarify, illuminate or shed light on." *Teaching* is also defined as "to enlighten and illuminate." Most dictionaries, it is true, do not include "to help make an emotional connection to…" in their definitions. But I think this may be a great idea, in science as well as in all other subjects.

Science is a construction created by humans to make sense of the world. Over the centuries, science has been invented, reinvented, and modified. It follows, or is supposed to follow, certain rules by which it operates. At first it was known as natural history or natural philosophy, and debate was its favorite mode of operation. Later Galileo opened the door to direct experimentation, and scientists such as Kepler, Brahe, Newton, and Darwin showed how the interpretation of data can lead to explanations and theories that allow us to predict, with fair accuracy, events and everyday occurrences, or to develop the technology to do tremendous things, such as to send humans to the Moon.

This book is based on everyday occurrences and the desire to understand and enjoy them. It is paramount that the teacher and student make "emotional connections" to the world they are trying to understand. An emotional connection to a flower or worm or insect may not be absolutely essential to knowing about it, but making an emotional connection to each and every critter on our planet and to its place in the ecosystem helps us see how we are involved, along with every *other* thing on our planet, as a fully participating part of the entire system.

One does not develop *values* out of knowledge alone. Values are what we do when no one is watching (for example, walking to the trash can to deposit litter even though no one is around to witness it). A value is apparent when we compost our vegetable matter or recycle our aluminum, glass, and paper or take our own bags to the market, even though there is no law to demand it. We do so because we have made an emotional connection to our planet. Thus I posit that we need to help our students make emotional connections to the enterprise of science and to understanding how our world works, as best we can interpret it.

Visitors to the Everglades National Park should be impressed, for example, by the realization that the plants they are viewing have survived six months of drought and six months of deluge (the Everglades is semitropical, with wet and dry seasons). They should understand that the plants have survived the two things that usually kill them, underwatering and overwatering. Most visitors know this about plants, and we build on this everyday understanding to motivate the groups to look for those attributes each plant has developed to adapt to this harsh climate. They begin to notice the waxy leaf covering, the shapes of the leaves, dormancy behavior, and other special features that mitigate the damage of too much water; however, these same plants also retain water during those times when there is little available. Visitors are awed when they meet baby barred owls that find this environment to their liking. Thus, the emotional connection is made. Hopefully, this leads to an understanding of the importance of protecting such an environment.

The students in your classroom can have the same experience. They should, whenever possible, make that emotional connection to the ocean, to a lever, to the condensation of water on a glass, to forces that affect their lives and their bodies, and certainly to the process of science itself. And I believe that I can safely say that without some emotional connection to topics in a curriculum, little will really be learned, remembered, and understood. This is why stories about children who live lives like theirs can help them make these connections.

Recently, a poem appeared on my desktop, which seemed to support some of the things that I have been advocating in my work in these volumes of everyday science mysteries. I ask you to remember the words and thoughts as you plan your teaching.

Leisure
by William Henry Davies (1921)

What is this life if, full of care,
We have no time to stand and stare.
No time to stand beneath the bough
And stare as long as sheep or cows.
No time to see, when woods we pass,
Where squirrels hide their nuts in grass.
No time to see, in broad daylight,
Streams full of stars, like skies at night.
No time to turn at Beauty's glance,
And watch her feet, how they can dance.
No time to wait till her mouth can
Enrich that smile her eyes began.
A poor life this if, full of care,
We have no time to stand and stare.

"Everyday Miracles"

I am often asked about the origin of these everyday science mysteries. The answer is that they are most often derived from my day-to-day experiences. Science is all around us as we go through our routines, but it often eludes us because, as the old saying goes, "The hidden we seek, the obvious we ignore."

I am fortunate to be surrounded by a rural natural environment. My daily routine is predictable. I arise, eat breakfast, and then walk with my wife through the woods for a mile or so to exercise our Australian shepherd and ourselves. Our dog acts as a wonderful model as she exhibits her awareness of every scent and sight that might have changed over the past 24 hours. Her nose is constantly sniffing the ground and air in search of the variety of clues well beyond our limited senses. As we walk, we look for our "miracle of the day." It may be a murder of crows harassing a barred owl or a red-tailed hawk flying over our heads with a squirrel in its talons. It might be a pair of wood ducks looking for a tree with a hole big enough for a nest or a patch of spring trillium or trout lilies. In the late summer, it could be a clump of ghostly Indian pipe and a rattlesnake plantain orchid in bloom or a hummingbird hovering near a flower fueling up for its long trip south. Today it is a gigantic, beautiful, mysterious, salmon-pink mushroom, never before noticed. Sounds from the road bring questions about how sound travels, and as we arrive home, we see crab apples, the worms in the compost pile, and the new greenhouse whose temperature fluctuations have plagued us all summer.

Textbooks are full of interesting information about the planets, space travel, plant reproduction, and animal behavior, but very little about how this information was developed. Our world is full of questions, many of which are investigable by children and adults. Our senses and mind are drawn to these questions, which stimulate the "I wonder…" section of our brains. We are intrigued by shadows, by the motion of the Sun and Moon during the daytime and the stars and planets at night. There are mysteries at every turn, if we keep our minds and eyes open to them.

I am amazed that so many years have passed without my noticing so many of the mysteries that surround me. Writing these books has had a stimulating effect upon the way I look at the world. I thank my wife, a botanist, artist, and gardener, for spiking my awareness of the plants that I glossed over for so many years. We can get so caught up in the glitz of newsworthy science that we are blind to the little things that crawl at our feet, or sway in the branches over our heads, or move through the sky in predictable and fascinating ways each and every day. One can wonder where the wonder went in our lives as we teachers get caught up in the search for better and better test scores. The stories spring forth by themselves when I can remember to see the world through childlike eyes. Perhaps, therein lies the secret to seeing these everyday science mysteries.

Writing Everyday Science Mystery Stories

When I first started writing stories, I tried the idea out with a seminar of my graduate students. We selected science topics, wrote stories about phenomena, and added challenges by leaving the endings open, requiring the readers to engage in what we hoped would be actual inquiry to finish the story.

Things to think about as you write your story
Does your story…

1. address a single concept or conceptual scheme?
2. address a topic of interest to your target age group?
3. try to provide your audience with a problem they can solve through direct activity?
4. require the students to become actively involved—hands-on, minds-on?
5. have a really open-ended format?
6. provide enough information for the students to identify and attack the problem?
7. involve materials that are readily available to the students?
8. provide opportunities for students to discuss the story and come up with a plan for finding some answers?
9. make data collection and analysis of those data a necessity?
10. provide some way for you to assess what their current preconceptions are about the topic? (This can be implicit or explicit.)

We also added distracters—children's ideas and misconceptions—that were intended to double as formative assessment tools. Over the course of the semester we wrote many stories and tried them out with students in classrooms. The children enjoyed the stories, and we learned some important lessons on how to formulate the stories so that they provided the proper challenge.

For years afterward, I used the idea with my graduate and undergraduate students in the elementary science methods classes. In lieu of the usual lesson plan, my class requirements included a final assignment that asked them to write a story about a science phenomenon and include a follow-up paper that described how they would use the story to encourage inquiry learning in their classrooms. As I learned more about the concept, I was able to add techniques to my repertoire, which enhanced the quality of the stories and follow-up papers.

I found that teachers benefit from talking about their stories with other teachers and their instructor. They can gain valuable feedback before they launch into the final story. We organized small-group meetings of no more than five students to preview and discuss ideas. We also designed a checklist document, which helped clarify the basic ideas behind the concept of the "challenge story." (See box.)

As usual, practice makes for a better product and finally my students were producing stories that were useful for them and were acceptable to me as a form of assessment of their learning about improving their teaching of science as inquiry.

As the years went by, teachers began to ask me if my own stories, which I used for examples in class, were available for them to use. They encourged me to publish them. I hope that they will provide you with ideas and inspiration to develop more inquiry-oriented lessons in your classrooms. Perhaps you may be motivated to try writing your own stories for teaching those concepts you find most difficult to teach.

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Introduction

Case Studies on How to Use the Stories in the Classroom

I would like to introduce you to one of the stories from the first volume of *Everyday Science Mysteries* (Konicek-Moran 2008) and then show how the story was used by two teachers, Teresa, a second-grade teacher, and Lore, a fifth-grade teacher. Then in the following chapters I will explain the philosophy and organization of the book before going to the stories and background material. Here is the story, "Where Are the Acorns?"

Where Are the Acorns?

Cheeks looked out from her nest of leaves, high in the oak tree above the Anderson family's backyard. It was early morning and the fog lay like a cotton quilt on the valley. Cheeks stretched her beautiful gray, furry body and looked about the nest. She felt the warm August morning air, fluffed up her big gray bushy tail and shook it. Cheeks was named by the Andersons since she always seemed to have her cheeks full of acorns as she wandered and scurried about the yard.

"I have work to do today!" she thought and imagined the fat acorns to be gathered and stored for the coming of the cold times.

Now the tough part for Cheeks was not gathering the fruits of the oak trees. There were plenty of trees and more than enough acorns for all of the gray squirrels who lived about the yard. No, the problem was finding them later on when the air was cold and the white stuff might be covering the lawn. Cheeks had a very good smeller and could sometimes smell the acorns she had buried earlier. But not always. She needed a way to remember where she had dug the holes and buried the acorns. Cheeks also had a very small memory and the yard was very big. Remembering all of these holes she had dug was too much for her little brain.

The Sun had by now risen in the east and Cheeks scurried down the tree to begin gathering and eating. She also had to make herself fat so that she would be warm and not hungry on long cold days and nights when there might be little to eat.

"What to do ... what to do?" she thought as she wiggled and waved her tail. Then she saw it! A dark patch on the lawn. It was where the Sun did not shine. It had a shape and two ends. One end started where the tree trunk met the ground. The other end was lying on the ground a little ways from the trunk. "I know," she thought. "I'll bury my acorn out here in the yard, at the end of the dark shape and in the cold times, I'll just come back here and dig it up!!! Brilliant Cheeks," she thought to herself and began to gather and dig.

On the next day she tried another dark shape and did the same thing. Then she ran about for weeks and gathered acorns to put in the ground. She was set for the cold times for sure!!

Months passed and the white stuff covered the ground and trees. Cheeks spent more time curled up in her home in the tree. Then one bright crisp morning, just as the Sun was lighting the sky, she looked down and saw the dark spots, brightly dark against the white ground. Suddenly she had a great appetite for a nice juicy acorn. "Oh yes," she thought. "It is time to get some of those acorns I buried at the tip of the dark shapes."

She scampered down the tree and raced across the yard to the tip of the dark shape. As she ran, she tossed little clumps of white stuff into the air and they floated back onto the ground. "I'm so smart," she thought to herself. "I know just where the acorns are." She did seem to feel that she was a bit closer to the edge of the woods than she remembered but her memory was small and she ignored the feelings. Then she reached the end of the dark shape and began to dig and dig and dig!

And she dug and she dug and she dug! Nothing!! "Maybe I buried them a bit deeper," she thought, a bit out of breath. So she dug deeper and deeper and still, nothing. She tried digging at the tip of another of the dark shapes and again found nothing. "But I know I put them here," she cried. "Where could they be?" She was angry and confused. Did other squirrels dig them up? That was not fair. Did they just disappear? What about the dark shapes?

How Two Teachers Used "Where Are the Acorns?"

Teresa, a veteran second-grade teacher

Teresa usually begins the school year with a unit on fall and change. This year she looked at the National Science Education Standards (NSES) and decided that a unit on the sky and cyclic changes would be in order. Since shadows were something that the children often noticed and included in playground games (shadow tag), Teresa thought using the story of "Cheeks" the squirrel would be appropriate.

To begin, she felt that it was extremely important to know what the children already knew about the Sun and the shadows cast from objects. She wanted to know what kind of knowledge they shared with Cheeks and what kind of knowledge they had that the story's hero did not have. She arranged the children in a circle so that they could see one another and hear one another's comments. Teresa read the story to them, stopping along the way to see that they knew that Cheeks had made the decision on where to bury the acorns during the late summer and that the squirrel was looking for her buried food during the winter. She asked them to tell her what they thought they knew about the shadows that Cheeks had seen. She labeled a piece of chart paper, "Our best ideas so far." As they told her what they "knew," she recorded their statements in their own words:

"Shadows change every day."
"Shadows are longer in winter."
"Shadows are shorter in winter."
"Shadows get longer every day."
"Shadows get shorter every day."
"Shadows don't change at all."
"Shadows aren't out every day."
"Shadows move when you move."

She asked the students if it was okay to add a word or two to each of their statements so they could test them out. She turned their statements into questions and the list then looked like this:

"Do shadows change every day?"
"Are shadows longer in winter?"
"Are shadows shorter in winter?"
"Do shadows get longer every day?"
"Do shadows get shorter every day?"
"Do shadows change at all?"
"Are shadows out every day?"
"Do shadows move when you move?

Teresa focused the class on the questions that could help solve Cheeks's dilemma. The children picked "Are shadows longer or shorter in the winter?" and "Do shadows change at all?" The children were asked to make predictions based on their experiences. Some said that the shadows would get longer as we moved toward winter and some predicted the opposite. Even though there was a question as to whether they would change at all, they agreed unanimously that there would probably be some change over time. If they could get data to support that there was change, that question would be removed from the chart.

Now the class had to find a way to answer their questions and test predictions. Teresa helped them talk about fair tests and asked them how they might go about answering the questions. They agreed almost at once that they should measure the shadow of a tree each day and write it down and should use the same tree and measure the shadow every day at the same time. They weren't sure why time was important except that they said they wanted to make sure everything was fair. Even though data about all of the questions would be useful, Teresa thought that at this stage, looking for more than one type of data might be overwhelming for her children.

Teresa checked the terrain outside and realized that the shadows of most trees might get so long during the winter months that they would touch one of the buildings and become difficult to measure. That could be a learning experience but at the same time it would frustrate the children to have their investigation ruined after months of work. She decided to try to convince the children to use an artificial "tree" that was small enough to avoid our concern. To her surprise, there was no objection to substituting an artificial tree since, "If we measured that same tree every day, it would still be fair." She made a tree out of a dowel that was about 15 cm tall and the children insisted that they glue a triangle on the top to make it look more like a tree.

The class went outside as a group and chose a spot where the Sun shone without obstruction and took a measurement. Teresa was concerned that her students were not yet adept at using rulers and tape measures so she had the children measure the length of the shadow from the base of the tree to its tip with a piece of yarn and then glued that yarn onto a wall chart above the date when the measurement was taken. The children were delighted with this.

For the first week, teams of three went out and took daily measurements. By the end of the week, Teresa noted that the day-to-day differences were so small that perhaps they should consider taking a measurement once a week. This worked much better, as the chart was less "busy" but still showed any important changes that might happen.

As the weeks progressed, it became evident that the shadow was indeed getting longer each week. Teresa talked with the students about what would make a shadow get longer and armed with flashlights, the children were able to make longer shadows of pencils by lowering the flashlight. The Sun must be getting lower too if this was the case, and this observation was added to the chart of questions. Later, Teresa wished that she had asked the children to keep individual science notebooks so that she could have been more aware of how each individual child was viewing the experiment.

The yarn chart showed the data clearly and the only question seemed to be, "How long will the shadow get?" Teresa revisited the Cheeks story and the children were able to point out that Cheeks's acorns were probably much closer to the tree than the winter shadows indicated. Teresa went on with another unit on fall changes and each week added another piece of yarn to the chart. She was relieved that she could carry on two science units at once and still capture the children's interest about the investigation each week after the measurement. After winter break, there was great excitement when the shadow began getting shorter. The shortening actually began at winter solstice around December 21 but the children were on break until after New Years. Now, the questions became "Will it keep getting shorter? For how long?" Winter passed and spring came and finally the end of the school year was approaching. Each week, the measurements were taken and each week a discussion was held on the meaning of the data. The chart was full of yarn strips and the pattern was obvious. The fall of last year had produced longer and longer shadow measurements until the New Year and then the shadows had begun to get shorter. "How short will they get?" and "Will they get down to nothing?" questions were added to the chart. During the last week of school, they talked about their conclusions and the children were convinced that the Sun was lower and cast longer shadows during the fall to winter time and that after the new year, the Sun got higher in the sky and made the shadows shorter. They were also aware that the seasons were changing and that the higher Sun seemed to mean warmer weather and trees producing leaves. The students were ready to think about seasonal changes in the sky and relating them to seasonal cycles. At least Teresa thought they were.

On the final meeting day in June, she asked her students what they thought the shadows would look like next September. After a great deal of thinking, they agreed that since the shadows were getting so short, that by next September, they would be gone or so short that they would be hard to measure. Oh my!! The idea of a cycle had escaped them, and no wonder, since it hadn't really been discussed. The obvious extrapolation of the chart would indicate that the trend of shorter shadows would continue.

Teresa knew that she would not have a chance to continue the investigation next September but she might talk to the third-grade team and see if they would at least carry it on for a few weeks so that the children could see the repeat of the previous September data. Then the students might be ready to think more about seasonal changes and certainly their experience would be useful in the upper grades where seasons and the reasons for seasons would become a curricular issue. Despite these shortcomings, it was a marvelous experience and the children were given a great opportunity to design an investigation and collect data to answer their questions about the squirrel story at a level appropriate to their development. Teresa felt that the children had an opportunity to carry out a long-term investigation, gather data, and come up with conclusions along the way about Cheek's dilemma. She felt also that the standard had been partially met or at least was in progress. She would talk with the third-grade team about that.

Lore (pronounced Laurie), a veteran fifth-grade teacher
In September while working in the school, I had gone to Lore's fifth-grade class for advice. I read students the Cheeks story and asked them at which grade they thought it would be most appropriate. They agreed that it would most likely fly best at second grade. It seemed, with their advice, that Teresa's decision to use it there was a good one.

However, about a week after Teresa began to use the story, I received a note from Lore, telling me that her students were asking her all sorts of questions about shadows, the Sun, and the seasons and aking if I could help. Despite their insistence that the story belonged in the second grade, the fifth graders were intrigued enough by the story to begin asking questions about shadows. We now had two classes interested in Cheeks's dilemma but at two different developmental levels. The fifth graders were asking questions about daily shadows, direction of shadows, and seasonal shadows, and they were asking, "Why is this happening?" Lore wanted to use an inquiry approach to help them find answers to their questions but needed help. Even though the Cheeks story had opened the door to their curiosity, we agreed that perhaps a story about a pirate burying treasure in the same way Cheeks had buried acorns might be better suited to the fifth-grade interests in the future.

Lore looked at the NSES for her grade level and saw that they called for observing and describing the Sun's location and movements and studying natural objects in the sky and their patterns of movement. But the students' questions, we felt, should lead the investigations. Lore was intrigued by the 5E approach to inquiry (*engage, elaborate, explore, explain, and evaluate*) and because the students were already "engaged," she added the "elaborate" phase to find out what her students already knew. (The five Es will be defined in context as this vignette evolves.) So, Lore started her next class asking the students what they "knew" about the shadows that Cheeks used and what caused them. The students stated:

"Shadows are long in the morning, short at midday, and longer again in the afternoon."

"There is no shadow at noon because the Sun is directly overhead."

"Shadows are in the same place every day so we can tell time by them."

"Shadows are shorter in the summer than in the winter."

"You can put a stick in the ground and tell time by its shadow."

Just as Teresa had done, Lore changed these statements to questions, and they entered the "exploration" phase of the 5E inquiry method.

Luckily, Lore's room opened out onto a grassy area that was always open to the Sun. The students made boards that were 30 cm^2 and drilled holes in the middle and put a toothpick in the hole. They attached paper to the boards and drew shadow lines every half hour on the paper. They brought them in each afternoon and discussed their results. There were many discussions about whether or not it made a difference where they placed their boards from day to day.

They were gathering so much data that it was becoming cumbersome. One student suggested that they use overhead transparencies to record shadow data and then overlay them to see what kind of changes occurred. Everyone agreed that it was a great idea.

Lore introduced the class to the *Old Farmer's Almanac* and the tables of sunsets, sunrises, and lengths of days. This led to an exciting activity one day that involved math. Lore asked them to look at the sunrise time and sunset time on one given day and to calculate the length of the daytime Sun hours. Calculations went on for a good 10 minutes and Lore asked each group to demonstrate how they had calculated the time to the class. There must have been at least six different methods used and most of them came up with a common answer. The students were amazed that so many different methods could produce the same answer. They also agreed that several of the methods were more efficient than others and finally agreed that using a 24-hour clock method was the easiest. Lore was ecstatic that they had created so many methods and was convinced that their understanding of time was enhanced by this revelation.

This also showed that children are capable of metacognition—thinking about their thinking. Research (Metz 1995) tells us that elementary students are not astute at thinking about the way they reason but that they can learn to do so through practice and encouragement. Metacognition is important if students are to engage in inquiry. They need to understand how they process information and how they learn. In this particular instance, Lore had the children explain how they came to their solution for the length of day problem so that they could be more aware of how they went about solving the challenge. Students can also learn about their thinking processes from peers who are more likely to be at the same developmental level. Discussions in small groups or as an entire class can provide opportunities for the teacher to probe for more depth in student explanations. The teacher can ask the students who explain their technique to be more specific about how they used their thought processes: dead ends as well as successes. Students can also learn more about their metacognitive processes by writing in their notebooks about how they thought through their problem and found a solution. Talking about their thinking or explaining their methods of problem solving in writing can lead to a better understanding of how they can use reasoning skills better in future situations.

I should mention here that Lore went on to teach other units in science while the students continued to gather their data. She would come back to the unit periodically for a day or two so the children could process their findings. After a few months, the students were ready to get some help in finding a model that explained their data. Lore gave them globes and clay so that they could place their observers at their latitude on the globe. They used flashlights to replicate their findings. Since all globes are automatically tilted at a 23.5-degree angle, it raised the question as to why globes were made that way. It was time for the "explanation" part of the lesson and Lore helped them to see how the tilt of the Earth could help them make sense of their experiences with the shadows and the Sun's apparent motion in the sky.

The students made posters explaining how the seasons could be explained by the tilt of the Earth and the Earth's revolution around the Sun each year. They had "evaluated" their understanding and "extended" it beyond their experience. It was, Lore agreed, a very successful "6E" experience. It had included the engage, elaborate, explore, explain, and evaluate phases, and the added extend phase.

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Chapter 9

Lookin' at Lichens

Rick and Jeannie were walking through the woods one morning. Suddenly, Jeannie stopped in her tracks and said, "Rick, look at this tree! It has white bark. I don't know of any trees that have completely snow-white bark, except maybe a birch. But this isn't a birch!"

Rick took a closer look and exclaimed, "Wow! You're right. This is no ordinary tree."

Now, Jeannie and Rick never took a walk in the woods without their magnifying glass and so they decided to look more closely at the strange tree with the white bark.

"It looks like it is one big white scab," said Rick, "and it completely covers the trunk of the tree."

"If you look at it closely, you can see that there are little bumps on it and some little black lines that look like they are raised above the surface!" Jeannie added, peering through the glass. "I wonder if we can peel it off and take some home for a better look under strong lights?"

"Let's try," said Rick. "Oh, man, this stuff is stuck right to the bark of the tree and won't come off unless we take some bark too."

"Well, I don't think we will hurt the tree if we take just a little bark," said Jeannie. And so they did.

But the walk was not over and they began to see all sorts of interesting things growing on the trees. But they were not all alike! Some looked like little flowers but were green all over. Some looked like plants that had overlapping scales. Many resembled the white stuff they had spotted on the first tree, but were red, pink or yellow. Once they began to notice them, it seemed like they were everywhere. They were on leaves, rocks, and even on the ground! They took a lot of samples and found that some of the little green things came off the trees where they were growing without much, if any bark. The ones on the rocks would not come off easily at all and the same was true of the ones on the leaves. When they got home, they found some on the door of the woodshed. Now they began to see them almost everywhere.

"Why haven't we noticed them before, I wonder?" asked Rick. "Now that we have noticed them, it seems like we can't find anything that doesn't have some of them growing on it. Look, there is even some on the railing of this stair up to the house. I wonder what they are?"

Jeannie and Rick knew Rebecca, a biologist at the local nature center and went to ask her. She looked at their samples and immediately said, "Those are lichens."

"Like-ums?" said Rick, "That's a funny name, but we do like 'em."

"No, lichens," said Rebecca. "L-I-C-H-E-N-S. They are very special kinds of organisms that are made up of two different kinds of living things. They live together, dependent on each other, in a way."

"How can we find out more about them?" the two young scientists asked together.

"Well, I can help you some, but I think you can learn a lot just by looking at them under a microscope or a magnifying glass. You can keep on collecting them. Maybe drawing them will help too."

Purpose

Lichens are everywhere, yet most people fail to notice them because they are so familiar. This story was written to help persuade teachers to acquaint their students with these unique forms of life. Many biology teachers, including myself, tend to gloss over the study of lichens and many of the other simple plants, even though lichens are universally available in virtually every environment, including urban centers. I hope that this story will help more students appreciate and become interested in them.

Related Concepts

- Fungi
- Algae
- Symbiosis
- Spores
- Reproduction
- Life cycles

Don't Be Surprised

Don't be surprised if your students have never noticed or expressed interest in the lichens. Lichens are not usually flashy, although some of them have beautiful patterns and colors. Your students are probably not aware of the kind of relationship the fungi and the algae have. Older students will probably have some knowledge of plants or animals living together in some form of mutually dependent relationship (*symbiosis*) such as the bacteria and protozoa in the guts of termites. But the association between the fungi and algae in the lichens is an entirely unique relationship, well worth studying.

Content Background

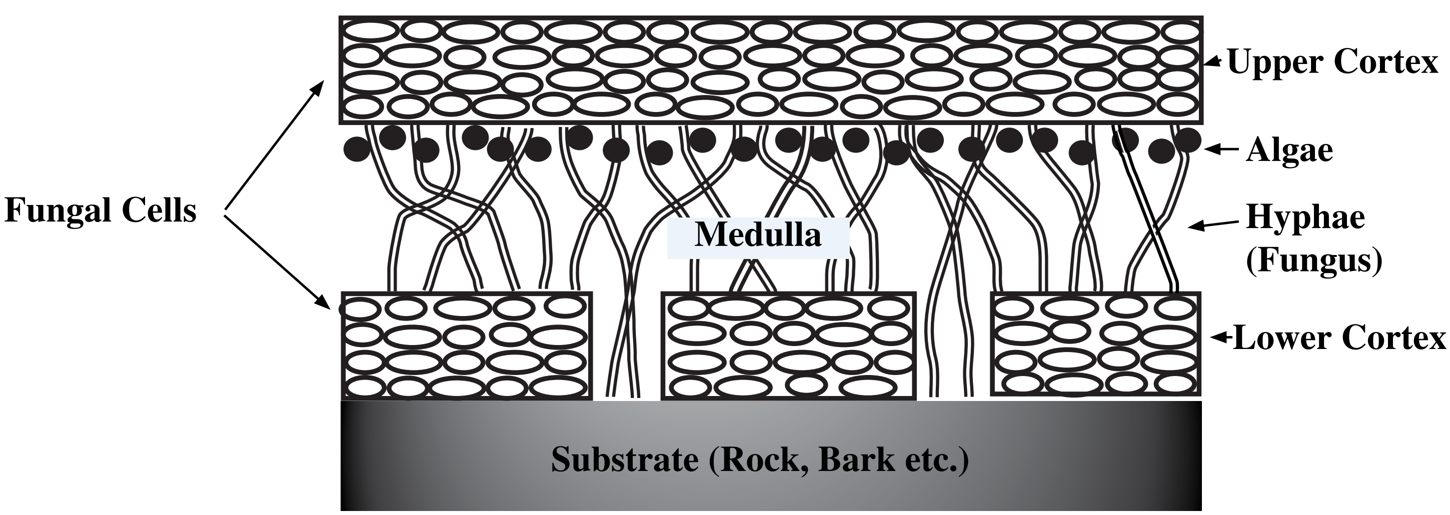
A *lichen* is a composite of a fungus and another organism that is capable of producing food through photosynthesis. The latter may be green algae or *cyanobacteria* (blue-green algae) or sometimes both. When two organisms have a biological relationship it is called *symbiosis,* and the partners are called *symbionts*. In lichens, the fungal part is called the *mycobiont,* and the algae the *phytobiont* or sometimes a *photobiont.* Lichens are named after the fungus partner since observing and classifying the algae is not practical because they are hidden within the *thallus*, or the body of the fungus. It was not until 1867 that anyone even thought that the lichen might be symbiotic, because the idea of two organisms living together as such was unheard of. It took until 1939 before the true nature of the lichen was proved and then accepted by the scientific community. You might find *Lichens of North America* (Brodo, Sharnoff, and Sharnoff 2001) of interest.

Neither fungi nor the two types of algae are members of the plant kingdom, but each belong to their own: fungi in the kingdom Fungi, the cyanobacteria (blue-green algae) in the kingdom Monera, and the green algae in the kingdom Protista. Monerans are single-celled organisms that have no membrane around their nucleus. Protista is a kingdom that seems to encompass everything that doesn't fit anywhere else, ranging from tiny protozoa to 30-meter-long kelp. It is important to realize that classification is somewhat arbitrary since it can change over time depending upon how the scientific community decides what traits define the organisms.

The algae in lichens provide sugars for the fungi, while the fungi provide protection from ultraviolet (UV) light for the algae and some predators that could kill or damage them. The algae live between two or three layers of fungi, like the filling in a peanut butter and jelly sandwich, which is a good analogy for the lichen form (or *morphology)*. The "bread" on top would correspond to what is called the *upper cortex* of the fungus layer, with closely packed fungal cells acting like skin. Beneath lies "jelly," the fungal filaments called *hyphae* in which algae are embedded. These hyphae may grow small tubes that reach into algae to extract the sugars produced by the algae's photosynthesis. Below that is the "peanut butter," which corresponds to the *medulla,* a fungal layer that is not so densely packed as the outer layers, and where many of the living functions of the lichen occur. Finally, in most (but not all) lichens, is the bottom layer of "bread," another tightly packed protective fungus layer called the *lower cortex*. This layer often contains structures that help the lichen attach to its host. Most fungi will combine with only one kind of algae but the algae are not as strict and may cohabitate with several different kinds of fungi.

Something called *morphogenesis* happens when the lichen and algae "marry." Neither organism is the same as it would be if it were found alone. Also, neither of the two organisms that make up lichen can be found living in isolation in the natural state. Only in the laboratory can the two be separated and examined as individuals.

Diagram of the Lichen Structure

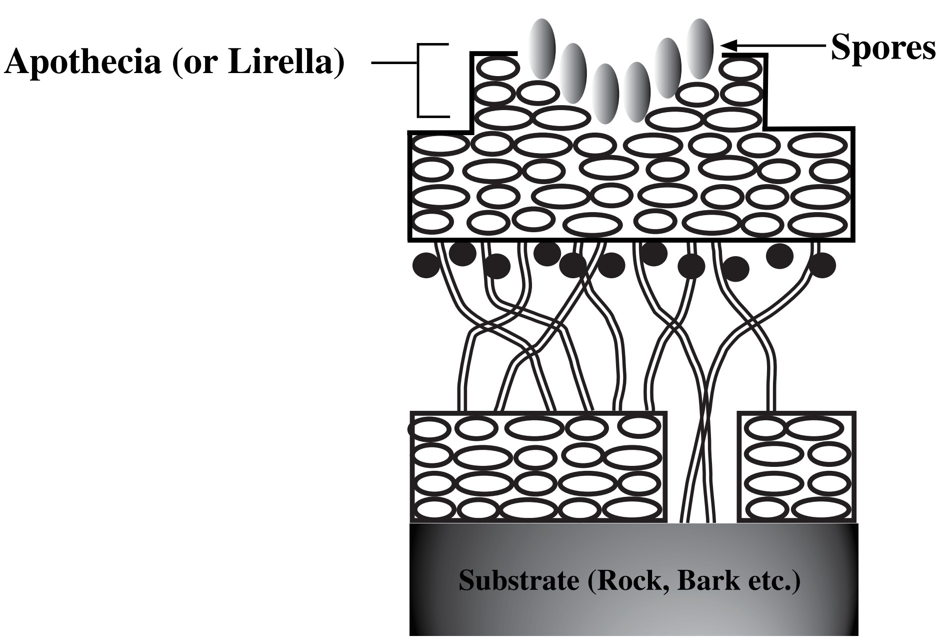


Even here, the resulting organisms are amorphous and fragile. Thus, each lichen is a totally unique organism, named, as stated before, for the fungal partner.

Even though we were taught in school that lichens were the epitome of a mutualistic symbiosis, recent research has shown that few if any lichen species are equal partners in the symbiosis (Brodo, Sharnoff, and Sharnoff 2001). *Mutualism* occurs when two or more organisms interact in a way that is beneficial to all parties. You and your students may immediately think of bees and flowers as examples. Flowers provide nectar for the bees that spread the pollen from flower to flower. Another example of mutualism is the protozoa that live in the gut of termites. The termites offer food and protection while the protozoa help to digest the cellulose (wood products) the termites ingest. The partnership in lichens ranges from mild parasitism by the fungi upon the algae to outright destructive behavior. Some fungi will actually kill their partner algae over time, but usually the photosynthetic partner will reproduce fast enough to keep ahead of the fungal aggressiveness. Lichenologist Trevor Goward described lichens as fungi that have "discovered agriculture" (Brodo, Sharnoff, and Sharnoff 2001, p. 4).

In lichens, the photobiont (alga) can reproduce sexually or asexually (but mostly asexually). The mycobiont (fungi) reproduce by means of spores that can likewise be the result of sexual or asexual activity. When the windborne spores are produced asexually, they often carry some of the photobiont material with them. The spores resulting from sexual activity must find suitable algae with which they can combine in order to become viable. If you look closely, you can see the cup-like *apothecia* or long, dark, narrow ridges called *lirellae* across the surface. Both of these structures contain spores and are often used to identify the species of the

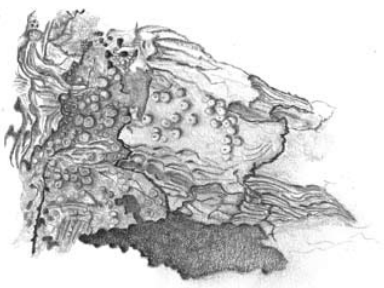
Lichen Spore Structures



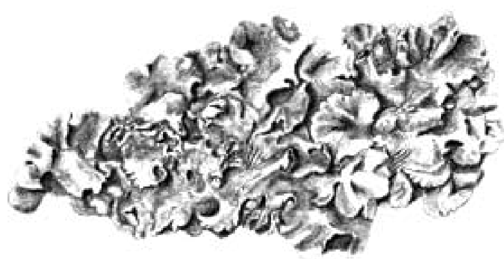
lichen. Lichens can also undergo vegetative propagation by having pieces of the thallus break off and become windborne to another location. This way, alga and fungus are kept together.

Lichens come in many forms and colors. *Crustose* (crust-like) lichens look as though they are glued to the bark of trees, leaves or rocks. This is likely the form of lichen found by Rick and Jeannie covering the tree. It is impossible to take them off in their entirety without taking some of the substrate (like the bark). We see only the upper parts of the thallus. The *foliose* (leafy) form of lichen is a little looser in its hold on the substrate, so we can lift and see both the upper and lower layers of the thallus. *Squamulose* (scale-like) forms show many overlapping parts of the thallus. The most dramatic lichen forms, the *fruticose* (shrubby) stand out from the substrate and may even look like moss or vines. One of these fruticose lichens is probably the most well known *and* misnamed, the so-called "reindeer moss," which is really a lichen (*Cladonia spp*).

Lichens are very difficult to identify to species levels. In order to distinguish one from another they often have to be keyed out by the chemicals that they produce.

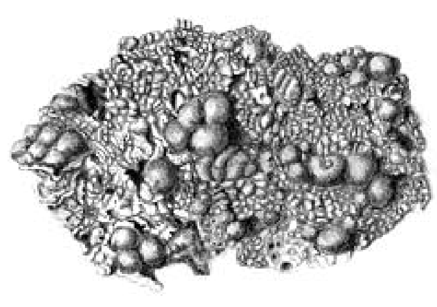


Crustose form of lichen: *Pertusaria xanthodes*



Foliose form of lichen: *Parmotrema cristiferum*

Fruticose form of lichen: *Ramalina complinata*



Squamulose form of lichen (10x) *Phyllopsera buettneri*

(Thanks to Rick and Jean Seavey for original reference photos)

These *metabolites*, as they are called, can be recognized through various chemical tests and through a process called *chromatography* that separates out chemicals on either paper or gel by using a solvent. These chemicals can also glow in the presence of UV light. Each species of lichen has a distinctive color emission when you bathe it in UV light, which is yet another way of identifying the organism.

Lichens know no bounds when it comes to climate or altitude. They range from sea level to mountaintops and from the tropics to the poles. They are found on any type of surface, including tree bark, leaves, plastic, rocks, soil, unwashed vehicles, and even on some insects.

Lichens provide food for many browsing animals and are capable of fixing nitrogen from the atmosphere into compounds useful by other organisms in the environment. They are also a "canary in the mine" in that they absorb pollutants and radioactivity so that their lack of health or even disappearance can be seen as a warning of polluted surroundings.

One interesting characteristic of lichens is that they can endure long periods without water and become revived quickly once water is restored. Therefore they are very resilient to climate and weather changes. If you find dried-up looking lichen, you can douse it with water and within a few minutes see the color return.

Despite the fact that they have been so often ignored, these organisms should invite a great deal of scrutiny because of their diversity and uniqueness, as well as their importance to the ecosystems of the world.

Related Ideas From the National Science Education Standards (NRC 1996)

K–4: The Characteristics of Organisms

- Organisms have basic needs
- Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.

K–4: Life Cycles of Organisms

- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interaction with the environment.

K–4: Organisms and Their Environment

- An organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms

present, the availability of food and resources, and the physical characteristics of the environment.
- All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organism or other organisms, whereas others are beneficial.

5–8: Structure and Function in Living Systems

- Living systems at all levels or organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans are multicellular.
- Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.
- Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of function that serve the organism as a whole.

5–8: Reproduction and Heredity

- Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually.

5–8: Populations and Ecosystems

- A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.
- The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resource and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Related Ideas From Benchmarks for Science Literacy (AAAS)

K–2: The Living Environment

- Some (organisms) are alike in the way they look and in the things they do, and others are very different from one another.
- (Organisms) have features that help them live in different environments.

K–2: The Interdependence of Life

- Living things are found almost everywhere in the world. There are somewhat different kinds in different places.

3–5: The Living Environment

- A great variety of kinds of living things can be sorted into groups in many ways using various features to decide which things belong to which group.
- Features used for grouping depend on the purpose of the grouping.

3–5: The Interdependence of Life

- Organisms interact with one another in various ways besides providing food.

6–8: The Living Environment

- Similarities among organisms are found in internal anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more importantt than behavior or general appearance.

6–8: The Interdependence of Life

- Two types of organisms may interact with one another in several ways; they may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.

Using the Stories With Grades K–4

The best way to start this exploration is to go on a field trip to the backyard, schoolyard, or anywhere there are trees, rocks, or objects upon which lichens grow. Take the trip yourself, first. If lichens are not available on school grounds, you can usually find them growing on tombstones in graveyards, particularly ones with limestone grave markers. Often, in older communities and even older schools, lichens readily grow on buildings. If you live in a mountainous region, the rocks will have lichens growing on them in abundance.

Most children and adults will have seen lichens, but think that they are stains on the rocks and trees. Closer observation will show that many of the "stains" are really living lichens. Each child should have a magnifying glass and a notebook to draw them in. Think about having a scavenger hunt, with teams of kids sent out to find and record the most lichens. For those lichens that can be taken back to the classroom, a digital projecting microscope can reveal the unique qualities of each. There are now digital microscopes on the market that allow you to save pictures to a computer. If your school has online capabilities, you can find many pictures of lichens on the internet through your search engine.

Another activity involves the careful scraping of the top cortex from the lichen to reveal the green algae layer below. This can be accomplished only with careful dexterity and should probably be done by the teacher and shown to the students in the best way you have at your disposal (microscope, digital microscope, or hand lens).

While looking for the lichens in the local environment your students can probably think of some interesting questions to investigate:

- What is the most common color of lichens we have found?
- What kinds of shapes did the lichens exhibit?
- What kinds of trees do lichens seem to grow on most often?
- What kinds of trees do lichens seem to grow on least often?
- How many different colors did we find?
- Do they grow on any particular side (direction) of trees?
- Are there different kinds of lichens on the same tree or rock?
- What was the most common kind of lichen found?
- If animals were in or on the lichens, what kind were they?
- Within a set area, how many lichens were found and what kinds?

As you can see, there are many questions about the location, type, and physical attributes of lichens. Looking at lichens that are brought back to the classroom can provide some interesting observations too. Be careful, lichens grow slowly and can be damaged, so only bring home as many as you absolutely need. Drawings of the lichens plus information gathered on the field trip should be carefully recorded in their science notebooks.

Using the Stories With Grades 5–8

A field trip to the immediate neighborhood is in order for the middle school group but you may wish to organize the trip differently than for younger students. Middle school students can set up an area where the lichens are most prevalent and then identify the trees where the most lichens are found. They might answer some of the same questions listed above and also add such questions as:

- What kinds of lichens are most prevalent on what types of bark?
- What types of bark are lacking lichens?
- Are colored lichens or plain lichens most often found on soil or on the rocks?
- Are there any lichens that seem to be trying to occupy the same space?
- What kind of lichens (crustose, foliose, squamulous, or fruticose) did they find?

If microscopes are available, have the students look at the lichens under low power and find the apothecia and lirallae if they are present. If the lichen is dry, have them place a few drops of water on the lichen thallus and then watch what happens as the water soaks in. Under microscopic view, they can scrape away a bit of the top of the thallus and get a view of the green layer containing the algae or cyanobacteria. They can also look for small organisms that might be lurking in the tangle of the lichen structure.

This may be an eye opening experience for most students and possibly for you as a teacher. Lichens are usually glossed over by most biology teachers, so this may be one of the few opportunities for your students to look at them closely. I can almost guarantee that once they are seen, they will hold your class's interest.

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