LESSON **11**

Looking at Colors


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Why do the flowers in the picture appear to be colored? What color would they be if there were no light?

INTRODUCTION

In Lesson 10, you used your spectroscope to observe colors emitted from light sources. Do you think the source of the light is the only thing that determines the colors that make up light that reaches your eye? Why do many objects appear to be colored when illuminated by white light? Why does the color of these objects appear to change when you look at them through transparent colored glass or plastic? In this lesson, you will use your eyes and spectroscopes to try to find the answers to these questions.

OBJECTIVES FOR THIS LESSON

Examine some colored objects and explain why they are colored.

Use a spectroscope to examine light before and after it passes through transparent colored sheets.

Predict and observe the appearance of different colors when they are viewed through transparent colored sheets.

Getting Started

1. One member of your group should collect the plastic box of materials and divide the materials between the pairs in your group.

2. Look at the transparent colored sheets and colored pencils you have been given. Discuss with your group why these objects are colored. Be prepared to share your ideas with the class.

MATERIALS FOR LESSON 11

For you

- 1 copy of Student Sheet 11.1: Looking at Spectra Through Transparent Colored Sheets
- 1 copy of Student Sheet 11.2: Looking at Colors Through Filters
- 1 spectroscope

For you and your lab partner

- Transparent colored sheets (red, green, and blue)
- Colored pencils (red, green, and blue)

Inquiry 11.1
Looking at Spectra Through Transparent Colored Sheets

PROCEDURE

1. Use your spectroscope to observe white light before and after it passes through each of the colored sheets.

A. Record your observations on Student Sheet 11.1: Looking at Spectra Through Transparent Colored Sheets, in a table of your own design.

2. Discuss your observations with your partner. Below are some questions you may wish to consider:

Is the spectrum observed through the colored sheets the same as the spectrum for white light?

Are more or fewer colors visible when you look through the colored sheets?

What do the colored sheets do to white light?

B. Write a short paragraph explaining your observations.

3. Sometimes transparent colored sheets are called color filters.

C. Why do you think the transparent colored sheets are called color filters?

4. Write a short answer to the following question:

D. What do red filters do to white light?

Inquiry 11.2
Looking at Colors Through Filters

PROCEDURE

1. Select the red, green, and blue colored pencils.

A. In the first column of Table 1 on Student Sheet 11.2: Looking at Colors Through Filters, make a swatch of each color. White and black have been done for you. Label each swatch with the name of the color—use the color name written on the side of each colored pencil.

2. Look at the color swatches through the red filter *only*. Hold the filter about 10 cm above the color, as shown in Figure 11.1. Do not place it on the paper. Record the appearance of each color in the "Red" column of Table 1.

Figure 11.1 *Look through the red filter at the color swatches in Table 1. Hold the red filter about 10 cm above the surface of the paper.*

3. Predict how the same colors will appear under the green filter. Record your predictions in Table 1.

4. Test your predictions and record the results.

5. Repeat the same procedure using the blue filter.

6. Discuss your observations with your partner.

   B. Did you notice any patterns in your results?

   C. Can you explain these patterns? Record any ideas you may have.

REFLECTING ON WHAT YOU'VE DONE

1. Review your explanations and observations on Student Sheet 11.2 before recording your responses to A–D on the student sheet.

   A. Draw a diagram that explains why a green object appears green when in white light.

   B. Draw a diagram that explains why a green object under white light appears black when the object is viewed through a red filter.

2. What will you observe if white light passes through both a red filter and a blue filter?

   C. Record your prediction and observations.

   D. Explain your observations.

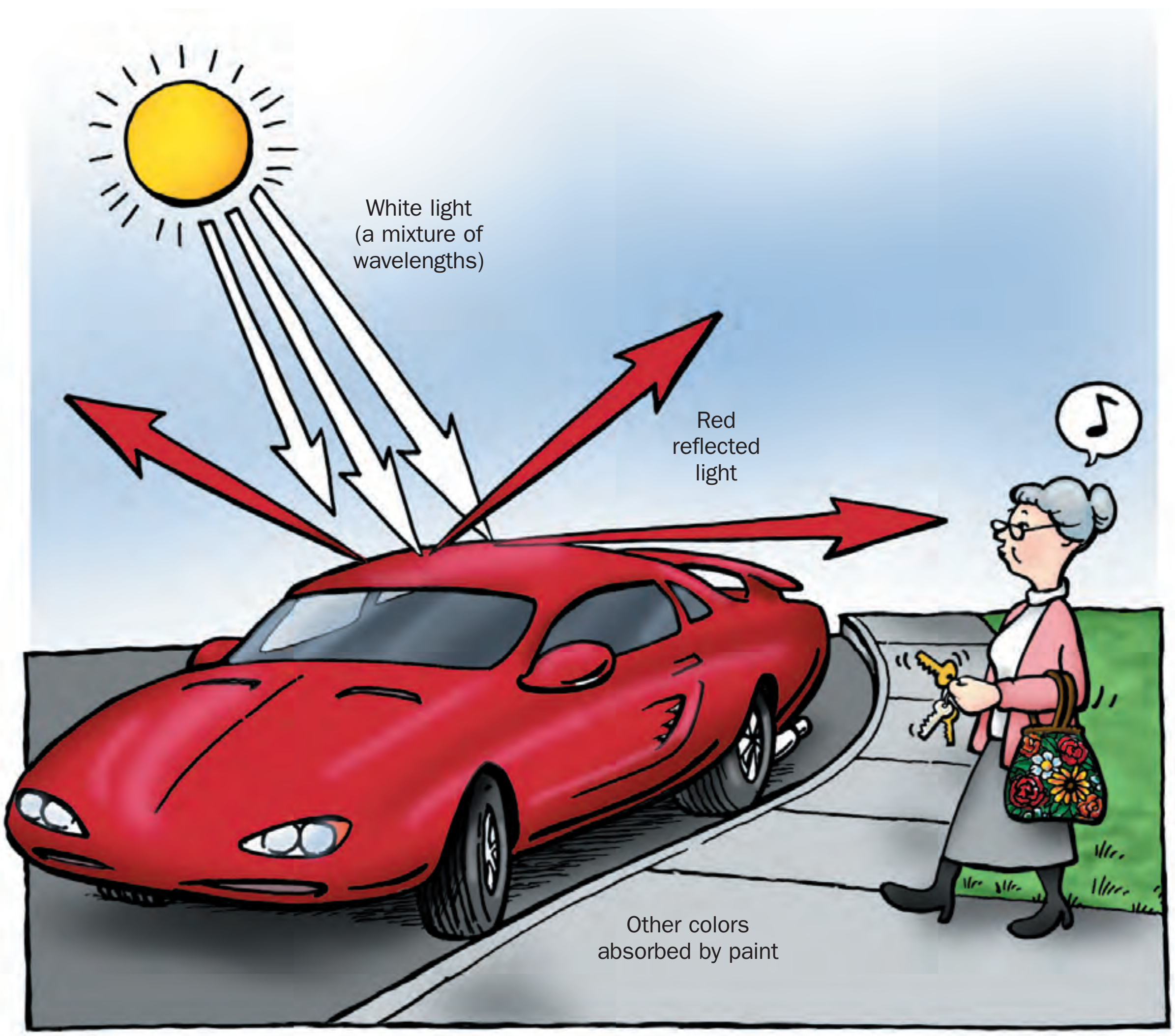
3. Read "Why Objects Look Colored." Think about the ideas you had at the beginning of the lesson about why objects were colored. Have these ideas changed?

Why Objects Look Colored

You can see objects because light travels from the objects to your eyes. Objects you can see are said to be visible. Light sources—luminous objects such as the Sun or a fluorescent lightbulb—are visible because they make visible light. But opaque, nonluminous objects do not make their own light. They are visible to your eyes because light from light sources bounces off them. In other words, light reflects off them.

Why do objects that reflect light appear to be colored? What, for example, happens when white light (made up of all colors of the visible spectrum) hits a yellow flower? The flower absorbs some colors in the white light and some—those that make up yellow—are reflected. You see this yellow light when some of it is reflected to your eyes.

Take another example. A red car looks red in white light because the car reflects only red light. The paint on the car absorbs the other



Why does this car look red? The paint on the car absorbs most of the wavelengths in white light and reflects only those wavelengths that look red when detected by our eyes.

colors. Most objects reflect some colors or wavelengths of light and absorb others. Only silvered mirrors or white objects reflect all colors. Only completely black objects absorb all the colors of the spectrum. No light reflects from the surfaces of completely black objects, so no light from black objects reaches your eyes.

Some colors may also be produced by reflection of more than one wavelength of light. However, your eyes detect these wavelength mixtures as only one color. This concept may seem confusing, but it is something you have already discovered. You see the paper of this page as white, but you know that the light reflected from the paper to your eyes contains all the colors of the visible spectrum.

Filtering Light

There is a slightly different explanation for why an object observed through a filter appears to be the color you see. Filters allow only some wavelengths of light through them—they transmit some colors and remove (absorb) others—in other words, filters filter out some colors (or wavelengths). So when you look at a sheet of white paper through a red filter, the paper

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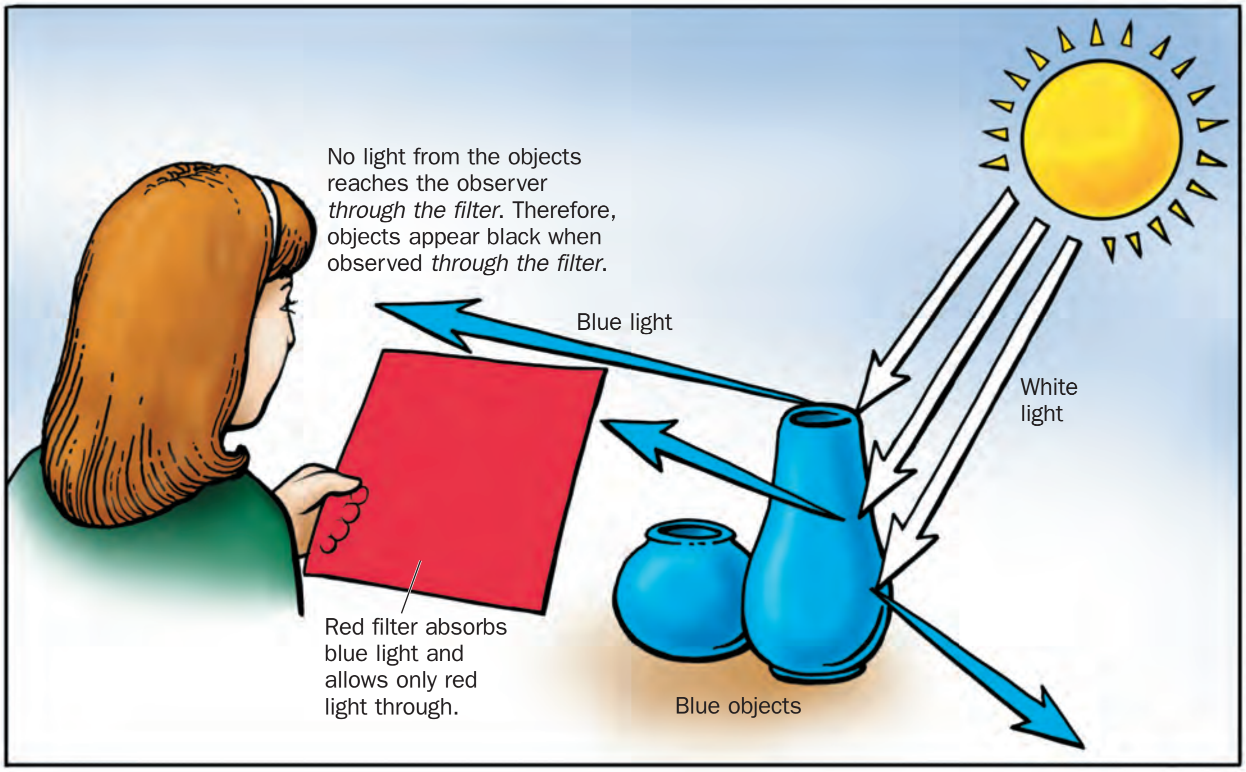
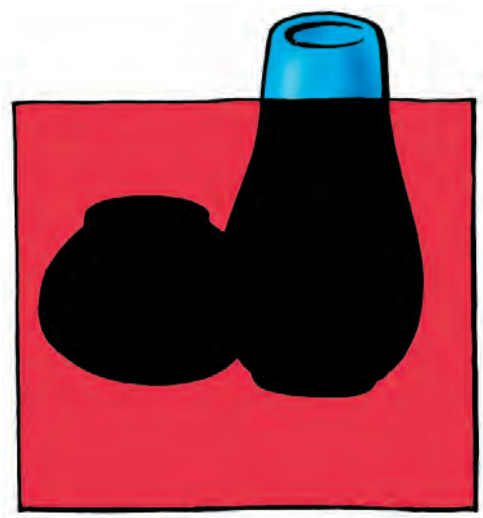
The lenses of sunglasses are often gray. They reduce the intensity of the sunlight by filtering out some of the light. Gray lenses are used so that all colors the eyes detect are reduced equally. The sunglasses produce a scene that is dimmer but still normally colored.



When viewed through a red filter, a blue object appears to be black. This is because the red filter absorbs the blue light reflected from the object.



What the girl sees

appears red. It looks red because the filter absorbs all the colors, except red, from the white light the paper reflects. Only red light reflecting off the paper reaches your eyes. If you look at a blue object through the same filter, the object appears black. This is because the blue object reflects only blue light; none of the blue light reflected by the blue object can pass through the red filter. Therefore no light from the object reaches your eyes—the object appears to be black.

Objects or filters look colored because they absorb or subtract some colors from white light. This process of producing color by subtracting colors or wavelengths from white light is called color subtraction. When you paint a picture in art class or look at a colored illustration printed in this book, the color you see has been produced by color subtraction. In the next reader, you will learn more about how people developed the techniques of color printing. □

PRINTING IN COLOR

Try to imagine a world without printed books, newspapers, or magazines. For many thousands of years people have used pictures and writing to communicate knowledge and ideas. But for most of this time, writing and pictures were not printed; they were copied by hand.

Buddhist monks in ancient China were the world's earliest expert printers. Over one thousand years ago, they used hand-carved blocks of wood to make thousands of copies of holy texts. The blocks were inked and then pressed onto silk and paper. The ancient Chinese were also the first to experiment with color in printed books.

While the Chinese already had developed their printing techniques, the Europeans were still hand-copying most of their books. Monks did most of this painstaking work. They then added color by hand in a process called illumination.

In monasteries throughout medieval Europe, books like these were copied and colored by hand.

This Buddhist text is called the Diamond Sutra*. It is the earliest dated printed book (A.D. 868). It was printed using carved wooden blocks.*

The Beginning of Modern Printing

THE CLIP ART BOOK, CRESCENT BOOKS, AVENEL, NEW JERSEY, 1994

Printers in Germany's Rhine Valley adapted existing technology for pressing grapes (for wine) and olives (for oil) to mechanize the printing process.

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Johannes Gutenberg led a revolution in printing using movable type that made the process cheaper and faster. Printing became one of the first mass-production processes. The page shown is from a version of a Bible produced by Gutenberg.

Mechanizing the Printing Process

More than a thousand years after the invention of printing, the process became mechanized. The printing press was invented.

We don't know who invented the first printing press, but we do know that printing quickly became big business. In the 1450s, a German printer, Johannes Gutenberg, invented a method of making metal letters (called type) and casting individual metal letters in standard-sized molds. This speeded up the printing process. It became much cheaper to print books and pamphlets. However, pictures were still hand carved on wooden blocks or metal plates. These pictures were black and white, but were sometimes colored by hand.

As books became more available, more people learned to read. The demand for books increased. People wanted to read about far-off places and exciting new discoveries. They wanted their books to have more pictures, and they wanted these pictures to be colored. This drove the development of color printing.

Color for Everyone

The first successful method of large-scale color printing (called lithography) was invented near the end of the 19th century. Originally in lithography, designs were drawn on fine-grained stone with a special oily crayon or ink. The stone was then moistened with water. Because water and oil repel each other, the oily picture did not get wet—only the rest of the stone. Oily ink was then rolled onto the wet stone. Again because water and oil repel each other, the ink stuck only to the oily picture, not to the surrounding wet part of the stone. Paper was then pressed against the stone to make a print of the picture.

To print in different colors, multiple stones were used. One stone was used for each color. The paper had to go through the press many times to be pressed against each inked stone. The stones had to be carefully aligned so that the colors were printed in the correct place.

This process was faster than the illumination process done by hand, but it was still slow. At first, books printed by lithography were very expensive. However, with improved techniques and mechanization, the process eventually became inexpensive enough to print magazines and advertising circulars in color.

FROM THE COLLECTION OF MILL GROVE—AUDUBON WILDLIFE SANCTUARY

This picture is from a book by the naturalist and painter John James Audubon (1785–1851). Early editions of Audubon's books contained hand-tinted pictures. Illustrations from later editions, like the picture shown here, used an improved type of lithographic color printing called chromolithography.

Printing With Dots

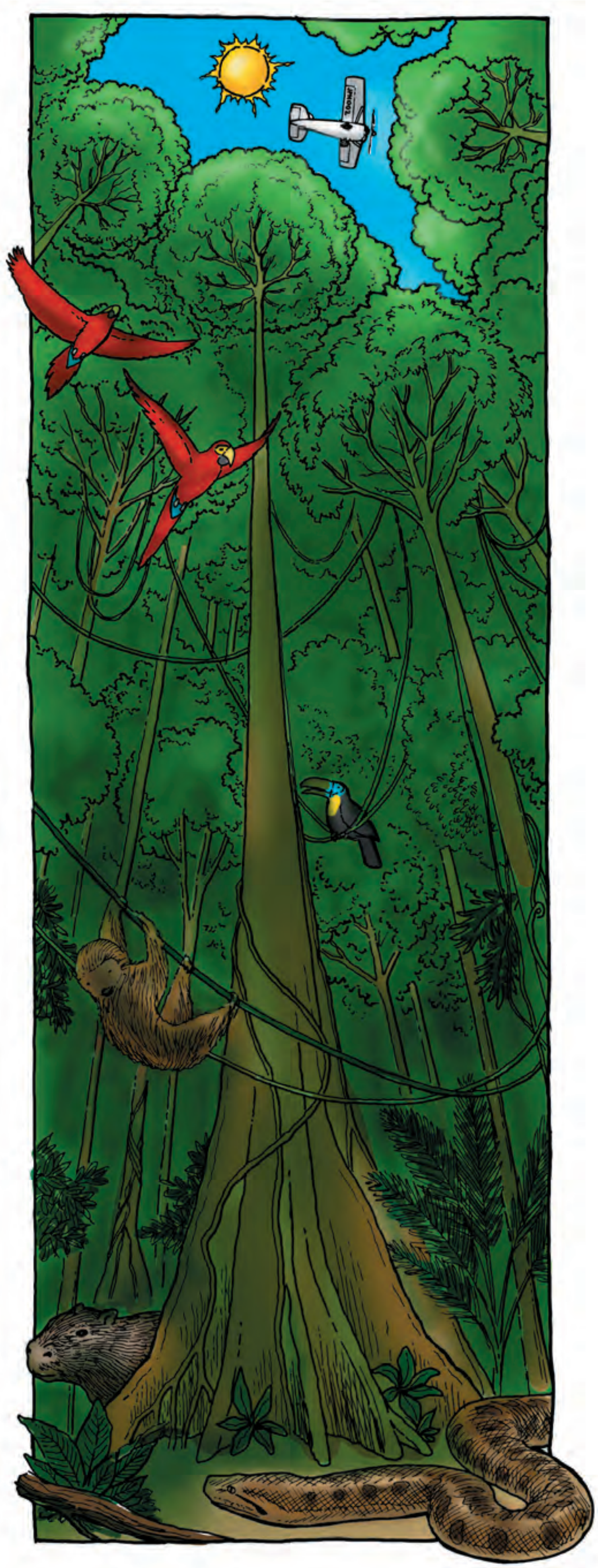
Modern color printing is based on a similar process. These days, a picture is scanned electronically and broken into four separate images. Each image represents one of the colors—cyan, magenta, yellow, and black—that will make up the picture. The scanner also breaks up each colored image into dots. The more numerous the dots of a particular color, the stronger that color. Each image is then photographically transferred to a metal (not stone) printing plate.

On the printing press, the paper passes under each of the four plates. Each plate holds a different color of ink. Without a magnifier, our human eyes cannot see the tiny dots that make up a picture. The colored dots all seem to blend together—just as they would appear if you mixed them from colored paints. But if you look at the picture with a powerful magnifier, you well see these colors break down into the four colors used to print them. ☐

PHOTOGRAPHY BY FERNE SALTZMAN, OFFICIAL BALLOON FIESTA PHOTOGRAPHER, © ALBUQUERQUE INTERNATIONAL BALLOON FIESTA INC.

In modern printing, four plates, each representing a different color—cyan, magenta, yellow, and black—are made. Use a magnifier to look at each picture. You will see they are made from dots of the four different colors. When these colors are combined, they produce a full-color picture.

A Green Engine Driven by the Sun



A giant snake slides silently across the wet floor of the Amazon rainforest. It's a 6-meter long anaconda—the largest snake in world—and it is searching for a meal. Perhaps it will find a juicy capybara, a sort of giant guinea pig. If it's lucky, it may catch an unwary sloth on one of the sloth's rare visits to the forest floor.

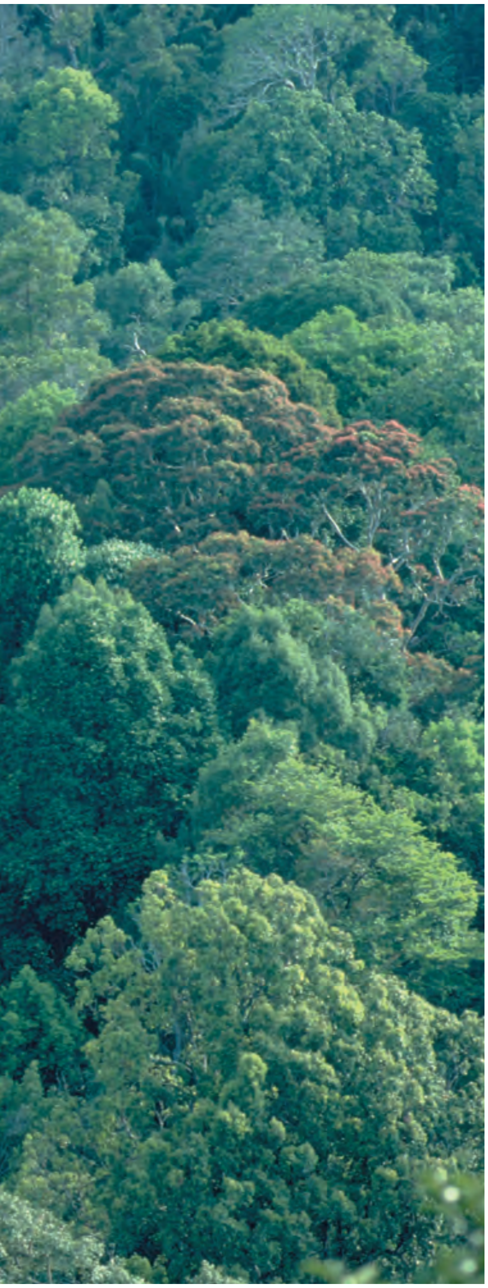
The anaconda's method of capture is to squeeze its victim in the giant coils of its body until the victim stops breathing. But all this slithering and crushing requires the snake to use its giant muscles. These muscles—and the snake's other life processes—use energy. The snake gets its energy from food—perhaps today it will be the sloth. Of course, the snake never stops to think where the energy in food comes from. Do you?

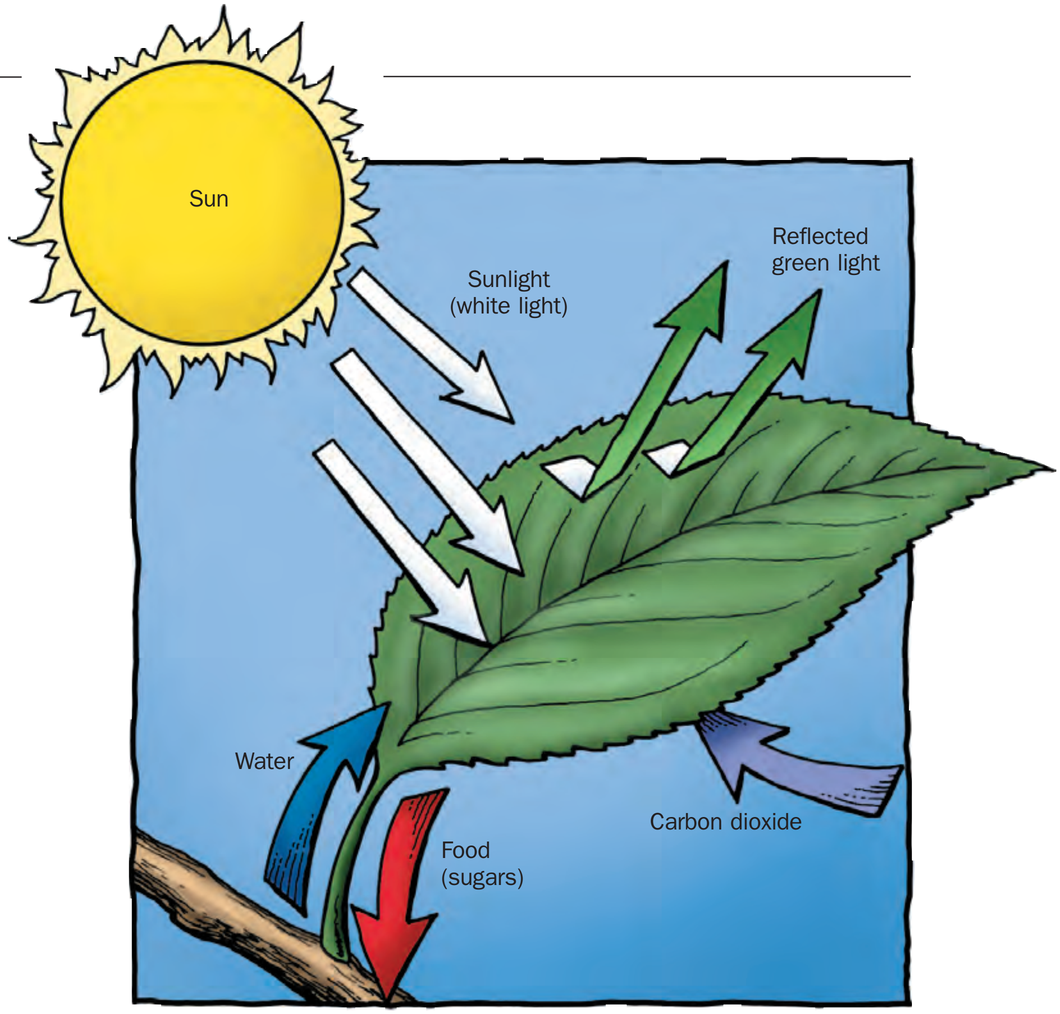

VISUALS UNLIMITED

Viewed from above, the green rainforest canopy hides the forest floor. Why is the canopy green? What is its function? These answers lie in the way chlorophyll absorbs and reflects sunlight.

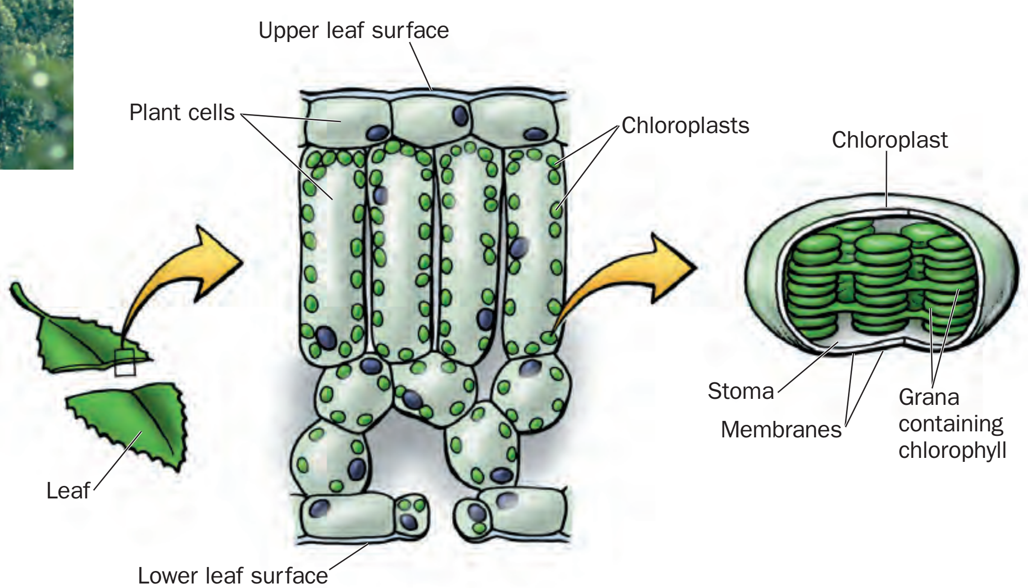
Above the hunting anaconda is a canopy of green formed by the giant forest trees. Viewed from above, the forest stretches out in all directions—green as far as the eye can see. Could all this green have something to do with how the snake gets its energy? In fact, this rainforest is an enormous food factory powered by sunlight.

A green chemical in leaves called chlorophyll harnesses the light energy from the Sun. Chlorophyll absorbs some wavelengths of sunlight and reflects others. The forest canopy looks green because its leaves reflect green light. Chlorophyll uses some of the light energy it absorbs to drive chemical





Inside each leaf, the process of photosynthesis takes place. Sunlight provides the energy for this process. What are the other raw materials involved?



Chloroplasts are found inside the cells of leaves. These microscopic organelles absorb certain wavelengths of sunlight and reflect others. What color do they usually reflect?

reactions. It transforms light energy into chemical energy—food. This food-making process is called photosynthesis, which means "making with light."

Inside each leaf cell are special tiny structures called chloroplasts containing chlorophyll. The flat leaves and the arrangement of chloroplasts in the cells are adapted to absorb sunlight. But plants need more than just chlorophyll and sunlight to make food by photosynthesis. Giant roots collect water from the shallow forest soil. Leaves absorb carbon dioxide from the air.

Each tree battles its neighbor for the resources needed for photosynthesis. The trees struggle upward competing against each other for light. Their huge roots and trunks support the branches and leaves of the canopy and also act as a highway for water and nutrients needed by the chloroplasts. Inside each chloroplast, the energy from the Sun is used to combine water and carbon dioxide (CO_2) to make sugars and starch. Each tree uses these substances to provide energy for its life processes. It also uses them to make more leaves, branches, flowers, and fruits.

The anaconda is the world's largest species of snake. It uses powerful muscles to squeeze its prey to death. These muscles use energy when they contract. Where does this energy come from?

These leaves and fruits will in turn provide food energy for the sloth and the capybara.

The unsuspecting sloth chews leaves as it carefully descends a tree trunk to the forest floor. The capybara feeds on fruit recently fallen from the trees. The trees of the rainforest canopy provide the sloth with food energy. But this canopy of trees also blocks out the sunlight. In the semi-darkness of the forest floor there is little protection from the anaconda. Nearby, the snake, hunting by its sense of smell, tastes the air with a forked tongue.

Suddenly, the snake seizes the sloth and wraps its long body around it. The snake has found the energy—food—it needs to sustain itself. It doesn't realize that this food energy has come indirectly from the Sun high above the forest canopy, through leaves of the forest to the leaf-eating sloth. The snake never sees the source of its energy. The Sun is hidden by the food factory of the forest canopy. ☐

This sloth spends most of its life in the trees of the Amazon Rainforest eating leaves. The energy in its food comes from the Sun. Sloths are often slightly green. That's because microscopic plants containing chlorophyll live in their fur.