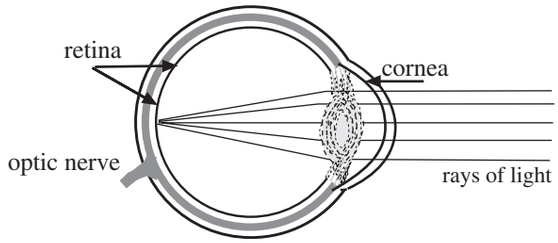

Figure 5.4 Light Focuses on the Retina

the object you were staring at. For example, if you stare intensely for 1 minute at a red dot and then turn your eyes toward a sheet of white paper, you will see a cyan (the complementary color of red) afterimage of the dot. Light reflected from white paper normally stimulates the red, green, and blue cones (photoreceptive cells) of the retina, but if you have first fatigued the red cones by staring at a red object, these cells temporarily will not respond to red light. As a result, only the green and blue cones in that region of the retina are stimulated, causing the image to appear cyan (the combination of green and blue light), the complementary color of red!

For this activity, color an American flag on an overhead transparency using the colors indicated in Figure 5.5, or project the flag image from the companion Web site of this sourcebook (*sciencesourcebook.com*). Instruct your students to cover one eye, and stare intensely at the middle of the flag with the other. After 1 minute, remove the transparency, and instruct students to keep their eyes focused on the same point on the white screen. They should soon see the American flag, correctly colored in red, white, and blue!

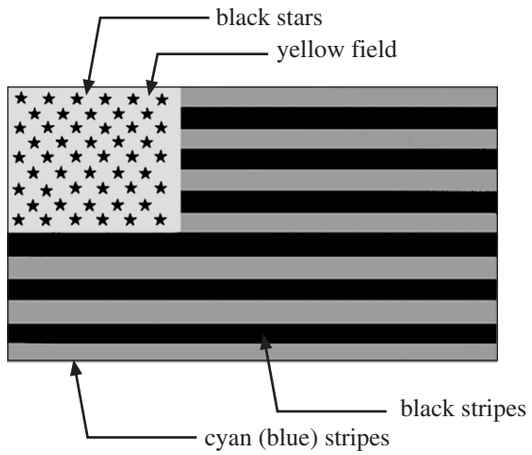

Figure 5.5 Flag in Complementary Colors

Instruct your students to draw a solid red circle on a white sheet of paper using a marker or paintbrush. They should cover one eye, place the circle in bright light, and stare at it. At the end of 1 minute, instruct them to quickly refocus on a well-lit sheet of white paper and ask them to identify the color of the afterimage (it will be cyan). Repeat this process with green and blue dots, and discuss the results. Students should identify magenta as the complementary color of green and yellow as the complementary color of blue.

Under normal circumstances, we don't see colors where none exist, so when students observe colors when they stare at a sheet of white paper, their curiosity is immediately aroused. You can use this discrepant event as an introduction to the importance of observation in the scientific method or to introduce students to vision and retinal physiology.

5.2 Developing Scientifically Oriented Questions

Michael Faraday (1791–1867) was a British scientist who invented the first electric motor and dynamo, demonstrated the relationship between electricity and chemical bonding, and discovered the effect of magnetism on light. Faraday was not only a brilliant scientist but also a well-known educator who brought science to the public through lectures he delivered each Christmas season at the Royal Society in London.[4] Faraday's Christmas Lectures were popular because he illustrated concepts with numerous hands-on activities and experiments.

Faraday knew the importance of observation in science and began his most famous lecture series by asking his audience to record as many observations as possible about a burning candle. Even today science teachers use Faraday's activity to encourage the development of observation skills. Douglas Osheroff, the 1997 Nobel Prize

winner in physics (for discovery of the superfluid phases of ^{3}H), reflected on the importance of this activity in his own intellectual development: "I remember quite well one class assignment: to record our own observations of a burning candle. I knew pretty well how a candle worked, and simply wrote down an explanation of how radiant heat from the flame melted the wax, which was then drawn up into the wick by capillary action, etc. Mr. Hock (the teacher) read my explanation, and then came to me and pointed out that what I had written could not possibly have been drawn from my own observations."[5] Osheroff had not made observations as requested but had relied on his prior knowledge to explain what he was seeing. Hock's comments helped Osheroff distinguish observation from inference, and this distinction ultimately helped him in his career as a scientist.

Table 5.1 Observations to Make About a Burning Candle

Flame
initial speed of burning
speed of burning once the wax starts to melt
height of flame in the open air
colors of flame
colors of flame light reflected off white paper
quality of light generated by flame
color distribution within flame
shape of flame
response of flame to air movement
response of flame to water
changes in flame height when beaker is lowered
changes in flame color when beaker is lowered
direction flame burns when candle is tilted
duration of smoke when candle is extinguished
time candle burns under large beaker
time candle burns under medium beaker
time candle burns under small beaker
shape of flame when water is placed in well

Condensate
appearance of condensate in beaker
conditions under which condensate forms
location where condensate forms
rate at which condensate forms
rate at which condensate disappears if flame is removed

Deposits
color of deposits on beaker
location where deposits form
rate deposits form on beaker
conditions under which deposits form
texture of deposits

Smoke
color of smoke
quantity of smoke
distribution of smoke
change in smoke production with funnel
distance from which candle can be relit
color bromthymol blue turns in the smoke

Candle (Paraffin)
color of candle
texture of candle
shape of candle
rate candle is consumed
appearance of wax when candle is burning
color of tip of wick when burning
rate candle is consumed if wax in well is drained
rate candle is consumed if wax is not drained
width of tracks left by flowing wax

Wick
position of wick of unlit candle
color of wick of unlit candle
structure of wick of unlit candle
ability of wick to burn if placed in water
ability of wick to burn if placed in lamp fluid
color of base of wick when burning
color of stalk of wick when burning
flow patterns of liquid wax
rate wick burns when not in wax
rate wick burns when in candle
apparent dryness or wetness of base of wick

Odors
odors produced by unlit candle
odors produced by burning candle
odors released by extinguished candle

Sound
sound produced by burning candle
sound of candle when water is placed in well

Heat
heat distribution around flame (top, sides, base)
side of hand that feels heat when near flame

ACTIVITY 5.2.1 ***Observations of a Candle***

Materials: small candle, matches, tongs, beaker, funnel, clay or putty, bromthymol blue or phenol red indicator, test tube clamp, safety glasses, dull butter knife, lamp oil (optional).

The purpose of this activity is to record as many observations of a candle as possible. Refer to Table 5.1 for ideas on the types of observations that may be made. Record your observations in a laboratory notebook or worksheet.

Firmly plant a candle in a small clump of clay. Using beaker tongs, suspend a clean, cool beaker over the unlit candle, as illustrated in (Figure 5.6A), and record your observations. Repeat the procedure with a funnel on which there are drops of the pH indicator methylene blue or phenol red (Figure 5.6B). Does the indicator change color?

Put on safety goggles, and light the candle. Record all observations (Figure 5.6C). Using beaker tongs, suspend a cooled beaker over the flame, as shown in Figure 5.6D. What observations can you make about the inside of the beaker? Repeat the procedure with a funnel in which there are drops of bromthymol blue (Figure 5.6E).

Place a dry, clean beaker over the flame (Figure 5.6F), and make observations as the flame is extinguished. Repeat the procedure with different sizes of glass beakers. Is there any correlation between the size of the glass beaker and the time it takes to extinguish the flame? Remove the beaker, and relight the candle by placing a match in the smoke near the wick (Figure 5.6G). Is it possible to relight the candle simply by moving the flame into the smoke?

Using a dull knife, cut the wick free from the candle, and place one end of the wick in a dish of water. Light the other end of the wick (Figure 5.6H). What do you observe? Dry the wick off, place it in a dish of lamp oil, and relight it. What do you observe?

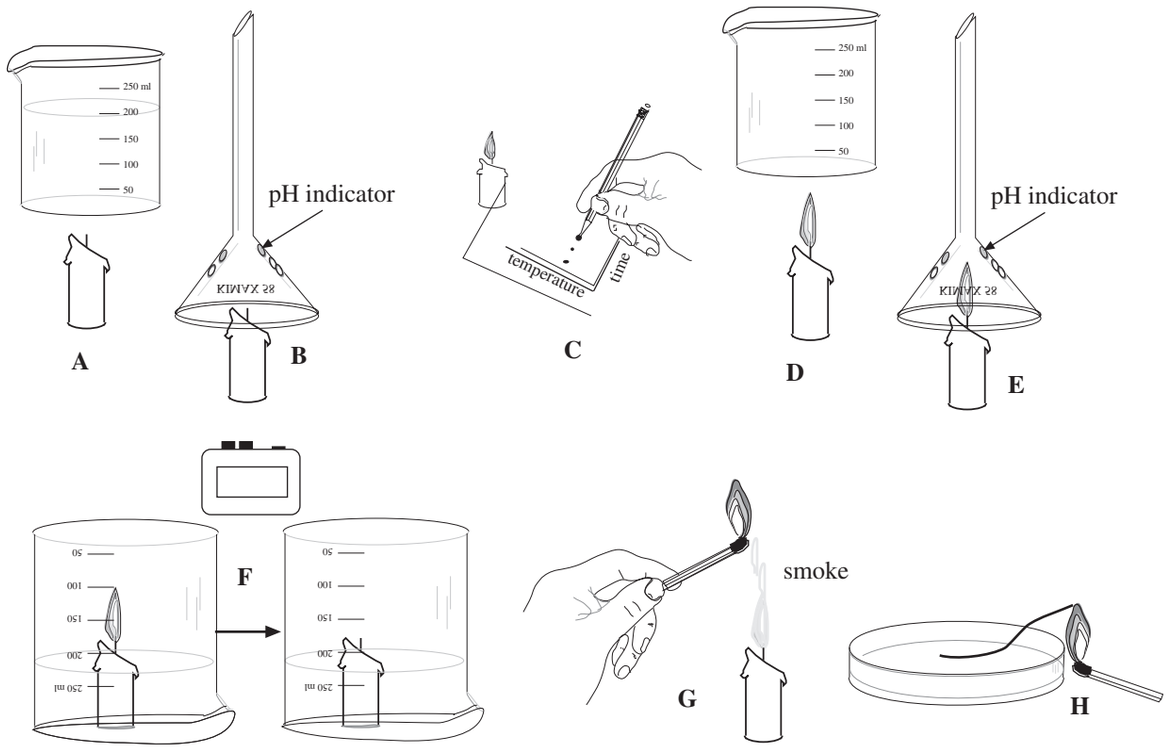

Figure 5.6 Observations of a Burning Candle