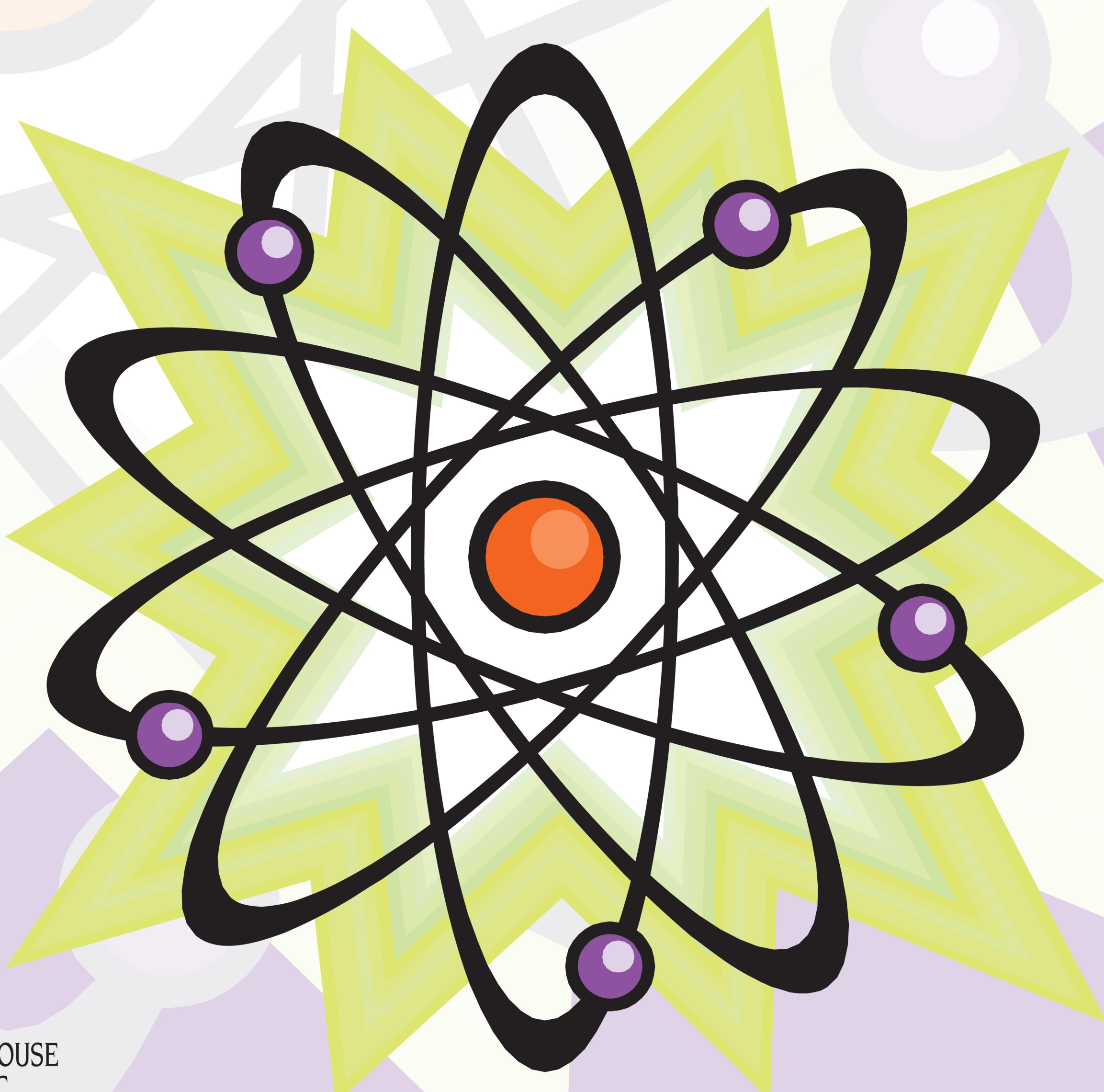
Basic Science Tactile Graphics

Teacher's Guide



American Printing House
For the Blind, Inc.

Basic Science Tactile Graphics

Teacher's Guide

Fred Otto, Project Leader
Tom Poppe, Model/Pattern Maker
Frank Hayden, Technical Assistant

American Printing House for the Blind
1839 Frankfort Avenue
P.O. Box 6085
Louisville, Kentucky 40206-0085

Cat. # 7-08850-00
©2002

Table of Contents

Introduction

Basic Science Tactile Graphics are vacuum-formed raised-line drawings depicting objects, concepts, and relationships, which are covered in nearly all elementary science textbooks. They are intended to supplement, not replace, the graphics in a student's adapted textbook.

This set of graphics may offer students a different presentation or vantage point from their brailled textbook graphics, and that in itself can be helpful. Each graphic also has a title, which textbook graphics often lack. The graphics in this set have the disadvantage of not being identical to any print graphic found in a particular science text, so blind students may not have the exact points of reference that the rest of the class is discussing. Thus, the vacuum-formed graphics and the braille textbook together make a good combination.

You may highlight or outline the figures on the vacuum-formed sheets with permanent markers for your low-vision students or for your own ease of use. Be sure to determine whether a student can better perceive thick or thin lines, and whether using different colors within a drawing is helpful, before marking up the materials.

Braille labels are provided on the drawings in order for you and the student to discuss the objects illustrated. You may wish to add to or change the labels by brailling on peel-and-stick paper, cutting the labels out, and applying them in the appropriate places on the diagrams. (If students are writing braille, you might involve them in this process.) This would allow you to use the same labels as in the corresponding drawings in the student's textbook, or to label the same drawing in different ways to illustrate different concepts.

Lines and Textures

The drawings in *Basic Science Tactile Graphics* employ several types of lines and textures, as well as different heights. The lines and areas with the highest relief signify the most important features in a diagram.

Often a very low dotted texture is used to fill in an area and distinguish it from other areas. In some cases, this dotted texture is not merely "filler" but shows the presence of actual objects; these cases will be noted in a key. Where the texture is not labeled or included in a key, it usually indicates an area of water.

Teaching Suggestions

All of the drawings in *Basic Science Tactile Graphics* set depict concepts, systems, or terms that are common to any elementary course in science.

Instructional hints are given for each tactile drawing in the set. These teaching suggestions are not meant to give innovative ways to teach science in general. They focus on *how* you might present the concepts to blind students and what blind students might find difficult about the drawing or the concept. The goal of the suggestions is to make sure the drawings serve as aids to learning science, not as obstacles.

It is exceedingly rare to find a tactile picture that stands on its own for the blind student to understand without explanation from the teacher. Even the most well-crafted tactile graphic cannot overcome the fact that perceiving through the sense of touch is different from perceiving with sight, and things that are easily apparent with sight are usually less apparent through touch. These graphics may help demonstrate patterns, relationships, and concepts in science just as print pictures do, but they always depend on verbal description that you provide to be effective. In other words, the graphics don't teach science concepts—you do!

Consider the range of pictures found in science books. You'll find front, side, overhead, and interior views, pictures of things real and imagined, and a scale from the microscopic to the cosmic. With sight, you can look at a picture and immediately take in the perspective—the essence of *how* the information is being presented—and, with this context, quickly focus on details of *what* is being conveyed. Using touch, this immediate grasp of the *whole* of the picture is not available. It must be pieced together through exploration.

As a teacher, you can help students understand a tactile graphic by explaining *how* the graphic is presented and *what* it shows. "This is an outline of North America with arrows showing the moving air masses, like they might show on the TV weather report." "This picture shows how the ocean floor would look if you could see the whole thing from a great distance." These different kinds of views require explanation and *demonstration*, because it can be confusing for a blind child to understand just what sighted people see and how things appear from different angles.

Keep in mind that when you use these tactile graphics, you are not only teaching students science, you are teaching them to read tactile pictures in general. This may seem like extra work, but if you can build up students' competence and comfort in reading graphics, you'll open up possibilities for them and prepare them for later academic success. Along the way you will introduce many concepts and, with luck, stimulate students to be active thinkers (that is, *scientists*).

The first four graphics in the set make a case in point. The first one, "Leaf Shapes and Veins," is very simple but gives an opportunity for early success and vocabulary building. The second, "Parts of a Seed," introduces the idea of a *cross-section* and an expanded scale. The third, "Germination of a Bean Plant," introduces *stages* within a drawing, as well as building on the cross-sectional or cutaway view concept. The fourth graphic, "Parts of a Flower," shows how parts of a picture can be superimposed on other parts, and how things can be exaggerated in size and shape to be shown more clearly. These visual tricks are easily handled with sight, but blind students need deliberate explanation to master them.

The Drawings

1. Leaf Shapes and Veins

Clockwise from the upper left, the leaves shown are the *redbud*, *elm*, *sycamore*, and *white oak*. Encourage students to trace around the leaf outlines several times, and to develop the habit of tracing the outlines of areas as a way of getting an overall feeling for a drawing.

Listed here are some features of the leaves you may want to draw attention to. By doing so, you introduce new vocabulary, and you encourage students to look for similarities and differences, not only between the leaves themselves but also between the leaves and other objects in the world.

The redbud is shaped somewhat like an upside-down heart, and its outer edge is smooth all around.

The elm, like the redbud, is very pointed at the top, but its edge is jagged like a saw blade. This is also known as *toothed*; ask students to guess why.

The sycamore is shaped like a five-pointed star or, with some imagination, like a hand. The five sections are called *lobes*. Leaves with five lobes are called *palmate* because of the resemblance to the palm of the hand. Work with students to trace all five of the lobes.

The white oak is another lobed leaf. Its edge is smooth, but it has deep cuts that make the lobes.

Some leaves, such as the redbud and sycamore, have most of their veins branching from the stem, or from a single point. Other leaves have a long central vein with smaller veins branching off from it, such as the elm and white oak.

Smaller veins branch off to the left and right from the central vein. When the branching-off places are paired (that is, the smaller veins branch from the same place or very close), the vein pattern is called *opposite*. The elm leaf shows this pattern. When the branching-off places are separated, the pattern is called *alternating*, as in the white oak leaf. Examining the central veins and branches gives students good practice in placeholding with one finger while following a line outward with another.

2. Parts of a Seed (cutaway view)

Before presenting this graphic, help students understand the concept of a "cutaway view" or cross-section. They will, of course, have seen inside various foods already, but may not be familiar with how the "insides" of things are commonly represented in drawings. Start with a piece of fruit such as an apple and note the general shape. Keeping the same orientation for the student, slice down the middle of the apple. Examining the whole apple and then the same apple cut in half produces different views; the cut-open view has the same *outside* shape but shows the insides as well. Have students repeat the procedure by putting the halves together and tracing the outer shape, then taking the front half away and examining the flat surface created by the cut. Explain that a "cutaway view" allows us to show parts of things that are usually blocked from view.

The bean seed in the drawing is, of course, greatly enlarged. This drawing is also the first in the set to include a key. If students haven't seen a key in drawings before, explain that it's used when there's not enough space for a full braille label, or when a texture is found in a picture that needs explaining. Students may need coaching in the process of referring back and forth from the labeled items to the key.

Opening up a real lima bean or fava bean should be a part of the process of discussing seeds. Dried beans that have been kept in a damp paper towel for two to three days should be easy to split open, and will usually have enough of a young plant sprouting inside to examine tactually.

3. Germination of a Bean Plant (3 stages)

This drawing shows another cutaway view, this time of the soil in which the bean plant grows. Students should understand that the viewpoint for this drawing is right down at the level of the soil, rather than from above as in the previous drawings. You may have them lie on their side on the ground to help them understand this “bug’s eye” view!

Bean plants are shown in three stages: The seed pushing its roots down into the ground; the young plant emerging from the soil and carrying the seed with it; and the plant making its first “true leaves” as the early leaves shrink and the seed goes away. Make sure students understand that the seed in this drawing is the same kind shown in the previous one, but shown its natural size. The young leaves inside the seed in the previous drawing are shown emerging from the seed in this one.

4. Parts of a Flower

The parts of this flower have been enlarged and spread out to make it easier to distinguish them by touch. It is, of course, important for children to examine different types of real flowers by touch and smell and to compare them to each other. Most types of lily are good to start with when examining by touch because their petals are easily pushed out of the way and their stamens are prominent. Once students have shown some understanding of the flower parts as shown here, have them look at other flowers with differently shaped stamens and petals.

5. Fertilization

The pistil in the previous drawing is isolated and greatly enlarged in this drawing of the fertilization process. Some of the pollen grains sticking to the top send down pollen tubes toward the ovaries, where they are fertilized and form seeds.

Help students understand the connection between this drawing and the previous one by having them trace the pistils in each. They are similar in overall shape but not in size. Students need to grasp the concept of *scale*—namely, that some of the same items are shown in the second drawing, but everything is made bigger so it can be examined more easily. Note that the pollen grains, which are just tiny dots on the stamens in the first drawing, are shown as large dots stuck to the pistil in the second.

6. Types of Roots

This "bug's eye" view shows the plants above and the roots below the soil. The dandelion has one main root, the *taproot*, and the grassy plant has many branching roots, which are *fibrous*.

The most prominent lines in the drawing are used for the root systems, but students should note the way the entire plants are shown. Encourage them to not view the plants just as jumbles of lines but to trace the individual leaves of the plants as they spread out.

7. Plant Cell

This drawing shows a plant cell greatly magnified. Let students know that the interior of the nucleus is actually a dense mass of structures like strings, not the simplified squiggles shown in the drawing, and that these control what the cell produces.

8. Sea Anemone

It may help students understand this cutaway view if you have them cut an inverted Styrofoam cup in half from top to bottom and compare it to the drawing. The intact cup corresponds to the upper drawing and the cut-apart cup corresponds to the lower one.

Students should be aware that a real sea anemone has many more tentacles than are shown in this simplified drawing.

9. Flatworms

The upper part of the page shows a planarian, which is a scavenger. The spots resembling eyes are organs for sensing light. The scale is, of course, greatly enlarged.

The lower part of the page shows a tapeworm, which is a parasite. The mouth is at the left end.

10. Segmented Worm

This drawing shows an earthworm, much enlarged. The small raised tick marks alongside the body represent the bristles that help the worm move through the soil. You can identify the mouth end of the worm because the thick raised band on the worm is always nearer to the mouth than to the tail.

11. Insect

This drawing illustrates the main exterior parts of an insect's body in an overhead view. All are labeled; the head, thorax and abdomen have abbreviated labels that refer to the key.

12. Egg (cutaway view)

The parts of this drawing are the shell and lining, the egg white, the twisted strands, and the yolk with its white spot.

13. Mitosis

Students will have to turn the page sideways to orient the drawing and its labels properly. Some textbook illustrations of mitosis include much more detail and more stages, and some show considerably less. This drawing shows four stages, beginning in the upper left and proceeding clockwise as indicated by the arrows and numbers. Stage 1 shows four pairs of chromosomes within the nucleus. To avoid cluttering the interiors of the drawings, the same chromosomes are shown reduced in size in stages 2 and 3. Make sure students understand they are the same structures in each instance!

In stage 4, a second cell identical to the original has been created. The arrow linking back to stage 1 indicates that these cells may begin the division process again.

Check with students to see if they recognize and understand *arrows* as they are used in drawings. The more quickly students can identify the arrows and their purpose in a graphic, they more attention they can give to other aspects of the picture.

14. Virus

This illustration of a typical virus shows the coil of DNA information inside. Students may need some verbal guidance to understand the shape as a pair of coiled lines, even though the lines are tapered to suggest one in the foreground and one in the background. As always, a three-dimensional model may help prepare for this understanding.

At the bottom is shown the area of attachment to a cell, by which the virus injects its DNA and disrupts the cell's functions.

15. Valve inside Vein (cutaway view)

The view of the inside of a vein in this drawing is enlarged and very stylized, but it illustrates an interior valve that allows blood to flow in one direction but not in reverse. The arrow shows the direction of blood flow. Students need to understand that the sides of the valve are flexible: they will spread apart to allow blood to flow one way, and they will come together to prevent its going the other way.

You can demonstrate this principle to students in a hands-on way. Have students hold their arms out with their hands pressed together.

Their hands represent the valve. To illustrate the flow through the valve, hold your hand on its side and, starting above the students' pressed hands, bring it down fairly swiftly through them. You should have no trouble passing through the "valve" in this direction. Next, with students' hands still pressed together, try to pass your hand through them in the other direction. You will run into the pressed fingertips and be unable to enter. This situation is mirrored, in a very small way, inside the veins of the body.

15. Blood Flow from Artery to Vein

This drawing omits some elements of the circulatory process, such as the role of the lungs in giving oxygen to the blood and the role of other organs in disposing of the waste matter. It focuses more broadly on the roles of the blood vessels and the direction of blood flow.

Explain to students that the parts of this drawing are greatly enlarged. On the left is an artery carrying blood from the heart. The arrow shows how blood flows into a branch and from there into successively smaller branches (the capillaries). There the blood picks up waste products from the cells and continues on its path to the veins and back toward the heart.

16. The Eye—Front View

This dual-purpose drawing shows the exterior features of the eye and illustrates the expansion and contraction of the pupil in varying light.

The key for the drawing includes three kinds of information: a letter abbreviation *(p)* for the pupil, a line pattern for the eyelids and lashes, and an areal pattern for the iris.

The upper part of the drawing shows the pupil enlarged under dim light conditions. In the lower part, representing bright light conditions, the pupil is noticeably smaller.

17. Parts of the Eye (Cutaway Side View)

Students need to understand that the front of the eye in this drawing is to the right and the back is to the left. The labeled parts are, from right to left, the pupil, iris, lens, retina, and optic nerve.

It is important to work at length with students to compare this drawing with the previous view of the eye from the front, and with a model of the eye if one is available. This helps them learn more about the way the eye works, which can make visually impaired students better able to advocate for their own needs and preferences in learning and in medical treatment. It also gives them practice in the spatial skill of comparing items from different views, a skill which will help them understand complex structures more completely. Here are some questions or points of discussion that may be helpful:

What features did you find in the front view that aren't included here? (eyelids and lashes)

What parts does this drawing include that aren't in the front view? (lens, retina, and optic nerve) *Why do you think these weren't included in the first drawing?* (They are hidden behind the front parts of the eye.)

Why do the iris and pupil have such different shapes in the two drawings? (The front view only shows the surface; the cutaway view shows the thickness of the structures.)

18. Image Formation on Retina

Start by having students compare the labeled eye on the right of this drawing with the one in the previous drawing. This one is smaller and faces to the left; only the general outline is similar. The lens and retina are labeled.

On the left is a shape labeled "object." The rays of light coming from it are textured to be *directional*; that is, they feel slightly smoother in one direction and rougher in the other direction. The smoother direction indicates which way the light rays travel.

The light rays enter the lens and change direction as they pass through. Note the point where the angled rays cross each other behind the lens. The result is an image formed on the retina that's inverted (upside-down and backward); the rays from the top of the object form the image at the lower part of the retina and vice versa. It's up to the brain to set these inverted images the right way again.

18. Refraction

A beam of white light made up of different colors enters the prism from the left. As it passes through, the various colors of light are affected differently because of their different wavelengths. The red parts of the light are affected the least, while the violet parts are angled a great deal. The overall effect is that the white beam passing through the prism is broken apart into a spectrum of colors.

Have students compare the lines at the top and bottom of the spectrum to confirm that the lower ones undergo a more dramatic “bending” in the prism.

19. Reflection

The top part of this three-part drawing shows a single beam of light bouncing off a smooth surface. The arrowheads indicate the direction of travel. Students should note that the angle of the beam as it reflects off the surface is identical to the angle at which it struck the surface.

The center part of the diagram also shows reflection from a smooth surface, but includes three rays of light. The middle line is lower in height to make differentiation easier. Note that the spacing and angles remain consistent after the reflection but that the top and bottom lines change places in the process. The top becomes the bottom and vice versa—their image is inverted.

The lower part shows reflection from a rough surface. The regularity of the light rays as they approach the surface is broken up and they scatter in different directions, so no coherent reflected image is formed.

There is a corollary for this in the realm of sound. As many people have experienced the smooth hard walls of an empty room or bathroom can produce relatively clear echoes, which are reflections of sound waves. Rooms with lots of obstructions, furniture or carpeting represent "rough" surfaces that scatter or absorb the sound waves and produce no clear echoes.

20. Curved Mirrors

Each of the two diagrams on this page shows a light bulb on the left and rays of light reflecting from a curved mirror on the right. The light rays are shown with differently textured lines to make them easier to follow as they pass through each other. As the mechanics of optical drawings tend to be difficult for students to grasp, you will need to give a lot of verbal and hand-over-hand guidance.

The upper mirror is *concave*. Note that the middle ray reflects back on itself, and that all the reflected rays are *focused* in the area where they pass through each other. Note too that the top ray (labeled *t*) reflects downward while the bottom ray (*b*) reflects upward, so the image of the light bulb reflected in the mirror is inverted for the viewer.

The lower mirror is *convex*. Note how the reflected rays spread outward; the image in this case would not be inverted.

21. Sound Frequencies

The top part of this diagram shows the high pitched sound produced by a whistle. The textured areas represent air molecules. Draw students' attention to the alternating bands of compressed (denser) and uncompressed (less dense) air; these show the frequency of the vibrations that produce the sound. Be sure to note for students that the curved lines delineating these bands of air are imaginary; that is, they are used in drawings to indicate a wave motion but are not visible.

The bottom part illustrates the relatively low pitch produced by the horn of a tuba. The air is not vibrated (compressed and decompressed) as rapidly; thus the frequency and the pitch are lower.

22. (Key)

23. North American Air Masses

This diagram uses tactile elements at different heights to illustrate the major air masses that influence weather patterns in North America. You should start with students by establishing that this is a map and that the low relief lines and dotted texture give an outline of the North American continent surrounded by water. Alaska and Mexico are shown incompletely at the upper and lower extremes, respectively. As students may not have seen many maps, it is important to spend extra time with this outline and what it represents.

The broad arrows are shown at the highest relief. Each arrow is associated with a two-letter label indicating the origin (continental or maritime) and relative warmth (polar or tropical) of the air mass. Help students understand that the arrows do not point to specific locations but indicate general directions of the air movements.

24. Cold Front

The drawing is oriented sideways on the page. Unlike the previous drawing, which presented an overhead view, this diagram gives a broad view of a cold front system from a ground level vantage. On the left is a solid raised area of cold air; the arrow indicates its movement to the right. As it pushes in, the warm air is pushed upward, as indicated by the arrows on the right. A towering cumulonimbus cloud piles up, loaded with moisture, as shown by the textured area. Some of the moisture falls to the ground as rain.

Students should understand that while the air masses are not visible, the clouds and rain are. This is because much of the invisible moisture carried in the warm air mass *condenses* and the collection of tiny droplets is dense enough to reflect light as a visible object—even though it can't be perceived by touch!

25. Warm Front

As in the previous drawing, an air mass is shown moving in from the left. This time it is a warm air mass, and it "rides up" over the cold air mass already present. At the highest level it forms wispy cirrus clouds, followed by a blanket of stratus clouds and the rain-producing nimbostratus.

26. Weather Symbols/Weather Map of U.S.

The top part of this drawing shows some of the symbols most commonly used in weather maps, and the lower part shows an outline map of the U.S. with symbols superimposed. Recall from the earlier illustration of air masses that weather systems generally move from west to east across the country. Once students are familiar with the symbols, you may have them examine the map and describe the conditions is depicts, aloud or in writing, in the style of a TV weathercaster: "A warm front is moving toward this area of high pressure in the center of the country," or "The east coast is getting rain, with thunderstorms to the south."

27. The Atmosphere

A number of things in this drawing may require special explanation for blind students. First, the drawing is only a *section* of a cross-section. The curving lines representing the Earth's surface and the (imaginary) divisions between the atmospheric layers would, if extended, come around to form complete circles. This view *zooms in* to show a part of the system in detail.

The textured areas depict the components of the atmosphere—air, dust, and moisture—and the lines depict imaginary boundaries between layers.

Working from the ground upward, the labeled areas are *troposphere*, *stratosphere*, *mesosphere*, *ionosphere*, and *exosphere*.

28. Earth's Layers

This simple drawing shows the relative thinness of the Earth's crust in comparison with the thickness of the mantle and the core. For a more hands-on model, have students examine a hard-boiled egg or an avocado cut neatly through the fattest part, or a peach cut through from top to bottom.

29. Volcano Formation (Cutaway View)

This two-part drawing illustrates possible formations resulting from eruptions of magma. Part 1 shows magma rising through the Earth's crust in two places. Help students understand the scale of the drawing; that is, the solid areas represent the thickness of the crust and the textured areas are vast underground pools of magma breaking through from below.

Part 2 shows, on the left, a lava dome formed by the magma spreading out over the land, and on the right, an explosion of lava and rock high into the air.

Ketchup packets from a fast-food restaurant may be an effective (if slightly messy) way to illustrate the concept. Make a small incision in the middle of one, then fold the packet back and squeeze it as students follow the flow of the ketchup with one finger. The ketchup should flow up and out and spread over the packet. With another packet, make a hole with a pin or a pencil point. This time, have students hold a hand a few inches above the packet as you fold it and squeeze. Be prepared—the "eruption" will be dramatic if you squeeze firmly enough! Have a damp towel ready for cleaning up.

30. Earthquake Shifts Earth Layers

This before-and-after drawing shows the effects of an earthquake on sedimentary layers in the Earth's crust. The cutaway view shows four layers of sediment, represented by four textured areas, and the labeled fault line along which the layers shift. Students need to know the fault line is not a real object but a breaking point or fracture that allows the areas of rock to slide past each other.

31. World Map Showing Earthquake Zones

32. Map of Earthquake and Volcano Zones

These drawings are presented sideways on the page and are meant to be used together. The first shows a rough map of the continents with their names abbreviated. The areas of greatest earthquake activity, mostly in the oceans or along coastlines, are shown with a low dotted texture.

The second drawing repeats the information in the first but omits the braille labels; added in are the areas of volcanic activity, shown as small circles. Although they are not identical, the volcanic areas and earthquake areas correspond very closely.

33. Ocean Floor (Cutaway View)

This view requires students to grasp both the notion of a cutaway view of the ocean and the extremely small scale of what is being shown. In the drawing the high line shows the land;

everything above the line is water or air and everything below is solid ocean floor. The ends of the line at the left and right represent continental landmasses.

It can be difficult to understand that these land masses are hundreds or thousands of miles apart, and that an island in the ocean is really a mountain rising up from the ocean floor far below. A model made from clay or Styrofoam and partly filled with water may be needed to illustrate the concepts in a hands-on way.

34. Moon's Effect on Tides

The gravitational pull of the moon on the Earth is represented here by an arrow. Students should note that, while the Earth is shown as circular, the area of water surrounding the Earth is shown in an exaggerated way as elliptical (or "stretched"). The pull on the tides is strongest on the side facing the moon, but it is mirrored to a lesser extent on the other side. The pulling makes the areas of water on the sides thinner. To illustrate this effect to students, use a "stress reliever" ball or a thick rubber band to show how elongation in one direction requires contraction in another.

35. Wave Breaking on Shore

The key point for students to grasp in understanding how a wave “breaks” is that the moving tide encounters drag from the ocean floor as the floor rises. While the water below slows down, the water at the top keeps moving ahead and eventually breaks over the top.

Make sure students see that the line representing the ocean floor slopes upward while the crests of the waves remain at the same level. You might describe the water as “stumbling,” and equate it to walking along at a quick pace and suddenly encountering a small step that causes you to pitch forward.

36. Sunlight on the Moon and Earth

The sun is not shown in this drawing but is presumed to be off to the right of the page. The textures on the moon and Earth are areas lit by the sun’s rays, and the areas without texture are in darkness. Students should keep in mind that neither the Earth nor the moon gives off visible light; rather, they reflect light from the sun. In the upper part of the drawing, the part of the moon lit by the sun isn’t facing the Earth, and so the moon isn’t seen (new moon). In the lower part, the moon reflects sunlight back toward the Earth and thus is visible to people on the side facing it (full moon).

36. Moon Phases

The lower part of this page shows the phases of the moon as it moves through its cycle. The textured areas outlined with a higher line represent what is seen from the Earth.

The lowest lines in the drawing provide a continuity of shape from one phase illustration to the next, but they do not outline visible parts of the moon. From left to right, the labeled phases are:

new, *crescent*, *quarter*, *gibbous*
full, *gibbous*, *quarter*, *crescent*

To recall which crescent is waxing and which is waning, just remember that the waning moon says "C you later." If the crescent points like the letter C, the moon is waning.

37. Summer and Winter Sunlight

This drawing shows how the Earth's orientation to the sun's light affects the seasons. As in the previous drawing, the textured areas represent where the sun's rays are falling. (Areas of day and night are also labeled in braille.)

Since there are so many spatial relationships to convey in this concept, you will probably need physical models to illustrate it. A ball, perhaps with a pencil or dowel through it to serve as an axis, may represent the Earth. A rubber band around the ball can be the equator, and exploration of the model begins with the discussion of how this imaginary line divides the northern and southern hemispheres. Next comes the rotation of the Earth around its tilted axis, with an explanation that the poles as shown in the model and the drawing are also not real objects. Follow this with the orbiting of the Earth around the sun, such that one hemisphere receives more direct sun at times and experiences summer, while the other experiences winter. A student's hand may represent the sunlight; have the student hold the hand still while the you rotate the ball under the fingers, showing how the angle causes more "sunlight" to fall on one hemisphere or the other depending on which way the poles are pointed.

With an understanding of the model, students may be able to see how the tilt angle means different amounts of sunlight for different parts of the Earth. The top half of the drawing shows winter in the northern hemisphere; most of the sun’s rays fall below the equator as the north pole angles away from the sun. The bottom half of the drawing shows the reverse; the pole angles toward the sun, and the northern hemisphere experiences summer.

38. Direct Rays and Slanting Rays

This drawing illustrates why sun’s rays from directly overhead provide more warmth than rays coming from a low angle. The top part shows the overhead light of the sun’s rays in summer; a shaft of sunlight with an area of 1 square feet falls on 1 square feet of ground. In the lower part of the drawing, another shaft of light has the same area but, because of the slanting angle, spreads out over 1.8 square feet of ground. This shows how, in the winter, the same amount of light energy is spread out over a larger area of the ground and thus provides less warmth.

One way to simulate the concept of an “area” of sunlight is to use a drinking straw. Have a student hold a hand out, and use the straw to blow a stream of air onto one of the fingertips. Keep the end of the straw close to the fingertip and blow gently. When you point the straw directly at the fingertip, the air will feel quite warm. If you angle the air across the fingertip, it will be cooler. The amount of air moving through the straw is the same in both cases, but the sensation of warmth depends on how much area the air spreads over. Practice this demonstration in advance to get a feel for how to point the straw and how much air to blow through it for best effect.

39. Elliptical Paths of Planets Around the Sun

The planets in this drawing are unnamed because only the general shape of the orbits is the focus. Different levels of relief are used to indicate the paths of the planets to make it easier to distinguish one path from another. The ellipses in this drawing have been made fairly elongated to accentuate how they differ from circles.

Students should note that each orbit is offset; that is, the sun is not at the center of any of the ellipses.

40. (Key)

41. The Solar System

As in the previous drawing, different levels of line relief are alternated to make them more distinct from one another. This drawing shows only the relative *positions* of the planets to the sun and to each other; it does not show their relative *sizes* or *distances* with any accuracy. Note that Pluto's orbit sometimes brings it within the orbit of Neptune, making Neptune the farthest planet from the sun for a period of time.

42. Stars in the Milky Way Galaxy

The dots in this drawing represent vast numbers of stars and star clusters. The upper part of the page shows a "top view," as if you were looking from a great distance above the general plane of the galaxy, and indicates the "arms" of stars spiraling out from the dense hub. Our solar system's relative location is marked.

The "side view" is also taken from an immense distance, but within the same general plane as the galaxy. Again, our solar system's location is marked.

It is generally considered difficult for a blind student to relate different views of the same object to each other without a lot of specific training. One way to help students practice this kind of association is to use a small pillow with a wide pillowcase or ruffle around the cushion. Lay the pillow out on a table for students to examine from above. Relate this to the top view in the drawing. Viewing the pillow (or the drawing) from the top shows more about its shape from one *side* to the other. Now hold the pillow and case in such a way that students can only examine along one side of it. This corresponds to the side view in the drawing. Viewing from the side shows more about the object's *height* from bottom to top. In other words, each different view gives one element of information the other one cannot provide, and all are needed to give a complete picture of the object.

43. States of Matter

The top half of the drawing represents the relative density of molecules in a solid, a liquid, and a gas. Students should note that the molecules in the solid form are arranged in an orderly way; in the liquid and gas forms they are more scattered.

43. Atom

This drawing shows how an atom is typically represented in pictures. In the center is the nucleus consisting of two neutrons and two protons. Two electrons are shown in orbit around the nucleus. Note the relatively small size of the electrons compared with the other particles.

The atom pictured is helium, as it has two protons and two electrons.

44. Molecules and Compounds

The top drawing shows an oxygen molecule, composed of two oxygen atoms joined together.

44. Water Molecule

The lower drawing shows a water molecule, with an oxygen atom and two hydrogen atoms joined. Because it comprises unlike substances, the molecule is also a *compound*.

45. Field Around Bar Magnet

The raised bar represents the magnet, and the dashed lines show the general pattern formed by iron filings within the magnet's field. Students should understand that this pattern is a simplification of a more crowded pattern they would not be able to distinguish with their fingers if they were to examine the actual filings and a magnet.

It will be helpful for students to have a solid familiarity with this basic pattern before they move on the next drawing, showing the interactions between magnetic poles. Work with students to see the symmetry of the pattern from top to bottom and from left to right. It may be helpful to cover the lower part of the pattern with an index card as students study the top part. Then flip the card over, as if it were on a hinge, to cover the top as students examine the bottom. Showing students how the "hinged" card flips may help them understand that the image also "flips" around the center, and may help them grasp the idea of *symmetry*.

46. Fields Around Magnetic Poles

Building on the pattern shown in the previous drawing, this one shows how the fields of similar poles repel each other and those of opposite poles attract.

Direct students' attention first to the middle section of each bar magnet. There they will find lines of filings radiating out from the magnets, just as in the previous drawing. Things start to change, however, in the area between two magnets. Where the poles are similar, the effect of the two fields is to push the filings out of the way—note the cleared area between the magnets. Where the poles are opposite, it's as if the filings are pulled between them in a tug-of-war.

Like the previous one, this drawing gives you a chance to teach symmetry for those students who are ready to practice the concept.

47. Inside a Battery

This cross-sectional illustration shows the interior of a common household battery. The labeled parts are the carbon rod in the middle (*r*), the chemical paste surrounding it (*p*), and the zinc casing (*z*).

Students may need help with the braille symbols inside the battery. The textured areas representing the paste are labeled with minus signs (-) and the center rod is labeled with plus signs (+) to indicate the negative and positive charges.

47. Flow of Current

This illustration builds on the one above it to show the flow of current from the negative (-) terminal of the battery to the positive one (+). The line representing the wire is *directional* in its texture, meaning that is feels smoother in one direction than in the other; the smoother direction indicates the direction of the current. This flow is also indicated with arrows.

On the right is a light bulb with “glow lines” around it to show it’s lit up. It is, of course, a visual convention to show light this way, but it may be worth explaining as students will encounter it from time to time in drawings. The glowing bulb is labeled in braille as well.

48. Circuitry Symbols

The top part of this page introduces some basic elements of circuit diagrams. Two symbols that may need explaining are on the top row: the open and closed switches. Make sure students understand they are identical except that the first one is swung open like a door on a hinge.

48. Simple Circuit Diagram

The lower illustration shows some of the symbols combined in an actual circuit. Help students follow around the path, starting with the battery in the upper left and moving clockwise around. You might have them name the symbols as they encounter them. You might also ask if the light bulbs would light up as the diagram is shown (they would not, because the switch is open).

49. Inside a Light Bulb

This drawing may help students appreciate the internal workings of a light bulb, which are normally inaccessible to touch. It will be helpful to have an actual light bulb on hand for examination and comparison.

On the left is the outer view available to sighted people. The labeled parts, from the top down, are the *filament* (*f*), *wire* (*w*), *glass insulator* (*g*), *metal base*, and *tip*. Students should understand that the filament is a tight coil of extremely thin wire that is hard to see, and this picture doesn't really show what it looks like.

On the right is a cutaway view with the outer glass removed and the parts slightly expanded. Here the wire, which enters at the tip and exits at the right, is textured to be directional. This indicates the flow of current up through the filament and out to the metal base. The metal at the tip, though it appears connected to the base, is actually insulated from it. Likewise, the glass insulator inside the bulb keeps the two ends of the wire from touching and creating a *short circuit*.

If you can do so safely, consider breaking open a real light bulb and removing all the outer glass. Guide students as they examine the inner parts and compare them to those in the drawing.

50. Airflow Around Wing (Side View)

Students will need some help understanding the viewpoint of the upper drawing, as it involves a side or cross-sectional view of an object (an airplane wing) that extends far away from the viewer. The object labeled *wing*, as it's shown, doesn't really resemble any kind of wing the students have seen.

Explain that in order to show how air flows around a wing, you need to show the air above and below the wing at the same time, and that a side view allows this.

Note how the side view of the wing looks a bit like the side view of a three-ring binder or folder, with a bulge at one end and the other end tapering to a point. It may help to illustrate this using a folder with a rolled-up paper tucked into it to create the bulging end. Let students examine the top surface first to get a feeling for the general shape of a wing. Then hold the folder in such a way that students can only trace the side edge, and orient it to match the orientation of the wing in the diagram. Work with students to show how this kind of “side view” allows you to see above and below at the same time.

The lines in this drawing are textured to show direction from left to right. Make sure students detect that the upper lines have to travel further, over the curve of the wing, and therefore faster than the lower ones. The difference in speed creates the lower pressure above the wing and generates lift.

50. Forces Acting on Airplane in Flight

The added features of the lower drawing are the body of the airplane and the small tail wing. Again, the viewpoint requires explanation because we're seeing the profile of one end of the wing *and* the plane at the other end of the wing. In other words, we are viewing things that are at different distances, one superimposed on the other.

As students learn to interpret this illustration, they see how flight is a matter of balancing the four forces, each of which comes from a different source: *gravity* (from the Earth), *lift* (from the forward movement of the wings), *thrust* (from the engines), and *drag* (from air friction).

51. Propulsion

This two-part drawing shows a sealed balloon at the top and a balloon with a hole in it at the bottom. In the upper picture, the forces of air pressure (represented by arrows) push equally throughout the inside of the balloon. In the lower picture, the forces are unequal, and the balloon shoots upward because there's no opposing force to hold it back. The direction of motion and the escaping air are both labeled in the lower picture.

This principle is easily demonstrated with up to three students and a textbook. Simply hold one side of the book yourself and have students gently pull the opposing sides. The book doesn't move because the forces are balanced. But when you suddenly let go, see what happens. The forces are unequal, and the book (and the person pulling it!) jumps away in the direction where pressure is still being applied.

52. Powering a Rocket

This drawing builds on the previous one and shows how the forces can be used to propel a rocket. The labeled parts are *oxygen*, *fuel*, and *combustion*. The direction of motion is also indicated.

The circular chamber where combustion takes place is designed to resemble the balloons in the previous drawing, to reinforce the concept of an upward force with no opposing downward force.

Basic Science Tactile Graphics

Teacher's Guide

Catalog No. 7-08850-00

AMERICAN PRINTING HOUSE FOR THE BLIND, INC.
www.aph.org