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3-D TEACHING MODELS FOR ALL

A series of activities that allow students to "see" through touch

Joan Bradley and Donna Farland-Smith

When a blind student enrolled in my biology class, I wondered how I would provide an equal experience for him, when so much of the subject is visual. I knew that the labs in my class really supported the lectures and that excluding him from these labs would not be fair. So I tried to create three-dimensional (3-D) models for my class with this student's visual impairment in mind.

Allowing a student to "see" through touch what other students see through a microscope was a challenging task. However, using the 3-D models I developed not only helped my visually impaired student, but also my students with learning disabilities and different learning styles. Even students with no known disabilities commented on the usefulness of these models.

This article presents the 3-D models I (Joan Bradley) designed. These models are meant to benefit all students and can be used to teach common high school biology topics, including the Punnett square, cell membranes, photosynthesis, and an array of microscope experiences.

The Punnett square

A Punnett square is a common tool used in biology classes to predict the outcome of crossbreeding parents of known genotypes, as Gregor Mendel did in his famous experiments with pea plants. A Punnett square can be made by taping old, cardboard, microscope-slide boxes together or from supplies bought at a craft store. Teachers can also purchase a craft box with a lid that keeps the various pieces contained; in the model shown in Figure 1, different-size pieces represent the alleles of a genetics problem. This manipulative model was mentioned in *The Game of Science Education* (Weld 2004).

Although Figure 1 is set up for a monohybrid blood typing or sex-linked problem, it can also be used for a dihybrid cross by simply placing the pieces that represent the parental generation outside of the box and adding another type of piece to the mix.

Punnett squares are useful tools for exams and practice problems. During one exam, my student with visual impairment asked the exam monitor—who works with this student during test taking—to write down that the large spool shape represented the normal X chromosome; the small spool shape represented the X chromosome carrying hemophilia; and the cube shape represented the Y chromosome. This is no different than another student writing X = normal, X^h = X with hemophilia, and Y = normal. With the 3-D Punnett square, my student with visual impairment followed the process and understood the genetics section as well as any other student.

One of my kinesthetic students was having difficulty with genetics problems, but when I demonstrated the Punnett square model, it was as if a light switch had been turned on. After using the Punnett square for both her homework and exams, this student said that she finally "got it." The

FIGURE 1
Punnett square.

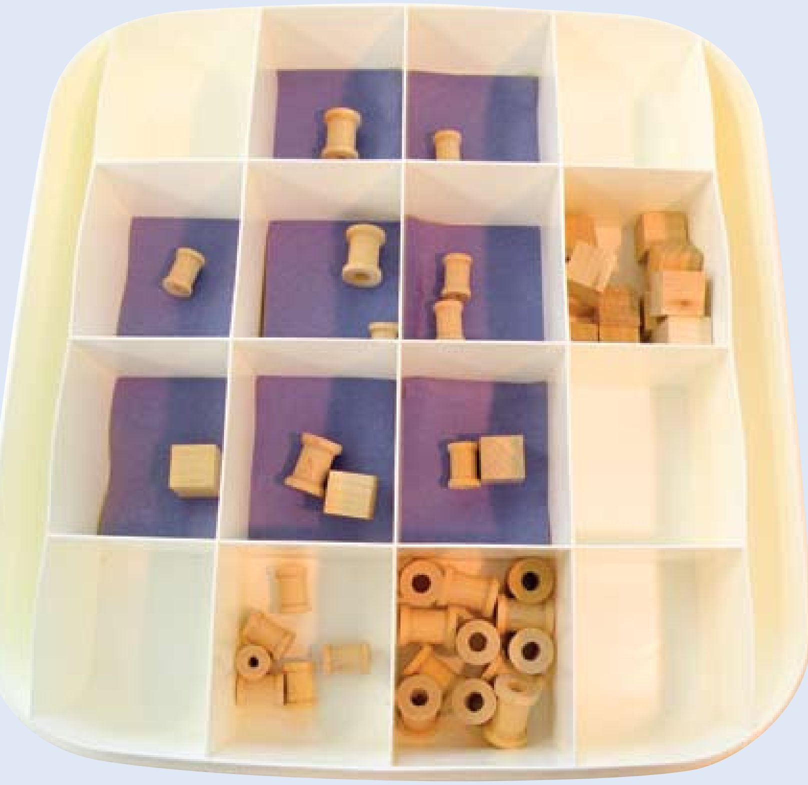
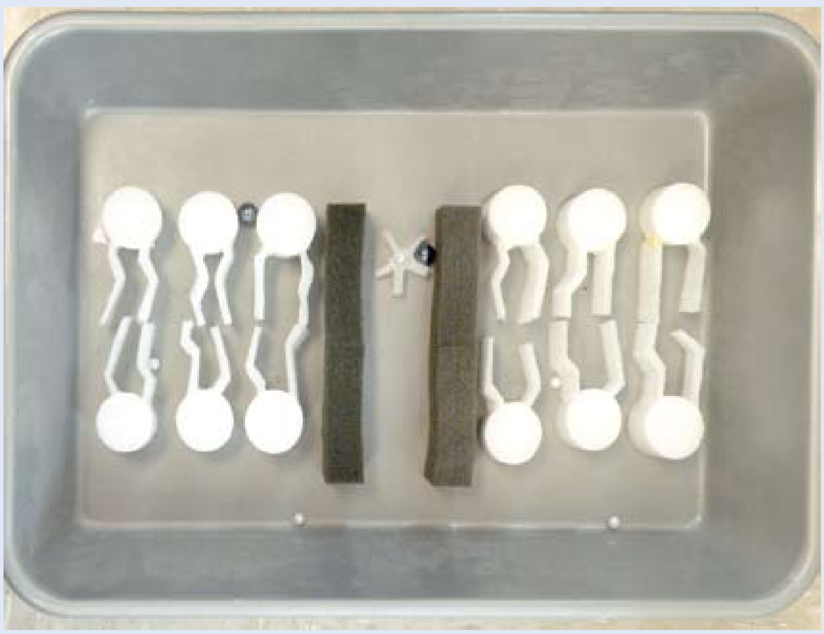


FIGURE 2
Phospholipid bilayer.



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Punnett square model cost approximately $8.50 to construct—but for all of these students, it was much more valuable.

Cell membrane model

I also created a 3-D cell membrane model to use with my students, shown in Figure 2. The white foam represents the phospholipid bilayer, and the black columns represent a transport protein through which molecules must pass. This model demonstrates passive transport—the movement of molecules across the cell membrane from high concentration to low. In this model, small beads make great small molecules because they can fit between the white foam; marbles, however, cannot fit through it, and therefore make great large molecules. When one end of the model is tipped up—representing high concentration—the beads and marbles are released from the top of the model; the beads pass through the bilayer, but the marbles can only move through the protein.

FIGURE 3A

Photosynthesis: Light-dependent reactions.

FIGURE 3B

Photosynthesis: Light-independent reactions.

Active transport is the movement of molecules against the concentration gradient; this can be demonstrated by moving the beads and marbles "uphill." This is only possible if students physically move them—their fingers are too big to fit between the white foam pieces, but can move through the protein—thus modeling the energy investment necessary for active transport.

After this lesson, I asked the following question on a quiz:

Large molecules move against the concentration gradient by moving through

A. the phospholipid bilayer without energy,
B. the phospholipid bilayer with energy,
C. the protein without energy,
D. the protein with energy, or
E. vesicle formation.

A student who had chosen answer B came up to me after the graded quiz was returned. In discussing this, I reminded him about the model and how his fingers did not fit through the bilayer, but did fit through the protein. The student shook his head and said, "I wouldn't have gotten it wrong if I had pictured the model!"

Photosynthesis models

Photosynthesis, represented by the models in Figure 3, can be a complicated process for many high school students to conceptualize. This model consists of two boxes: one representing light-dependent reactions (Figure 3a, the "photo" part of photosynthesis) and the other representing light-independent reactions (Figure 3b, the "synthesis" part of photosynthesis). In the photos, the left side of each box holds the reactants, and the right side holds the products.

In these models, a fairly common object represents each product or reactant. Water is represented by a faucet, light by a lightbulb, oxygen by an oxygen mask, energy by a battery, hydrogen and electrons by wooden H and E letters, carbon dioxide by a glove filled with air, the Calvin Cycle by a tricycle, sugar by sugar cubes, starch by elbow macaroni, and nicotinamide adenine dinucleotide phosphate (NADP) and adenosine phosphate (ATP) by trucks. Students typically laugh when I show them these objects, but the boxes help them remember which molecules are used in each portion of the reaction. They see the reasoning behind the tricycle for the Calvin Cycle when I explain that it begins with a three-carbon chain. On exams, I ask students to describe photosynthesis, and in the margins, I often see notes such as "light-dependent reactions (LDR): faucet/water, bulb/light" and so on.

Cell models

Students commonly build their own cell models at home to help them understand and conceptualize a cell's functions. There is, however, a simple, inexpensive way to create cell models in class that does not take up too much instruction time. Sandwich bags can be used to represent cell membranes and small plastic jars to represent the cell wall. The sandwich bag filled with hair gel represents cytoplasm. A variety of beads represent various organelles: green for chloroplasts, larger beads for the nucleus, and so on. Hook-and-loop fasteners represent the smooth endoplasmic reticulum (loop side) and rough endoplasmic reticulum (hook side). The use of color made the models more appealing to my sighted students, and my student with visual impairment was still able to recognize cell structures through touch and texture.

When assembling this model, students often realize that the cell membrane is tight against the cell wall. Many students admit that they did not fully understand this concept when observing cells through a microscope, but that it made perfect sense after working with the model. One student said, "I got the questions right about which organelles were in a cell because I remembered the cell I put them in!"

I created models of both small and microscopic organisms using ceramic clay to replicate the sighted experience of microscope observations. Although the models were brought out specifically for my student with visual impairment, other students began using them as well—and even asked if they could paint them to look more like the slides. I then found colored, polymer clay that can be baked at home. This clay is less fragile than ceramic clay, so it is easy and inexpensive to use. Figure 4 is a model of an *Aspergillus* fungus. To create this model, I placed wire in its center and then used the wire to pierce the "spores" and hold them in a stacked position. I then baked the polymer with the wire in place.

In some cases, the specimen was delicate or small, so I used polymer clay to represent these as well; one example is the moss plant shown in Figure 5a. This was beneficial for students, as they did not have to worry about damaging the specimen, and could use it to discuss alternation of generation and describe the sporophyte and gametophyte.

I used wire, felt, and puff paint to create a larger-than-life-size gametophyte and sporophyte model of a fern (Figure 5b). The size of this model made it easy to demonstrate in front of the entire class and allowed my visually challenged student to feel the model and conceptualize. Figure 5b shows the model from the front, and 5c shows the bottom.

In trying to offer more complex slides, I assembled a third model using quilt templates, puff paint, and wire.

FIGURE 4
Aspergillus.

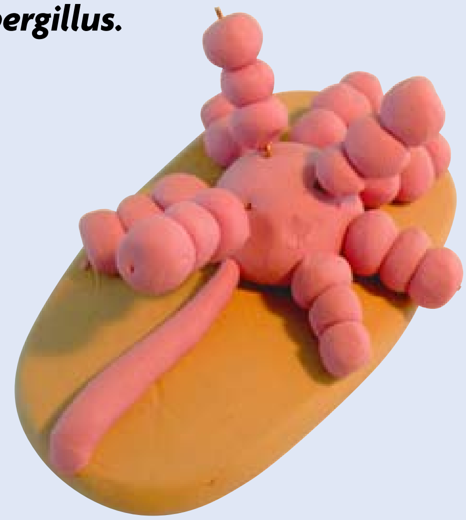

FIGURE 5A
Moss plant.

FIGURE 5B
Fern gametophyte and sporophyte (front view).

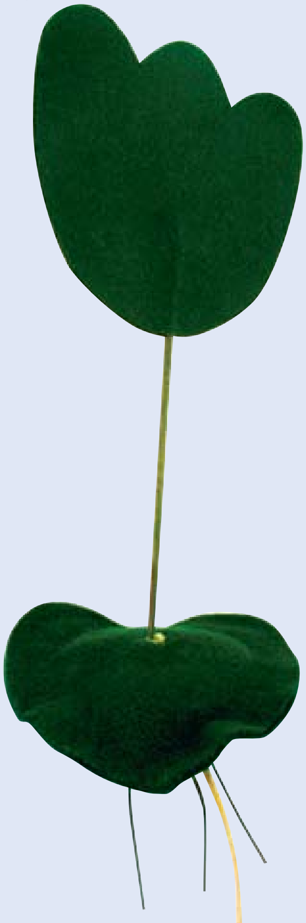

FIGURE 5C
Fern gametophyte and sporophyte (bottom view).

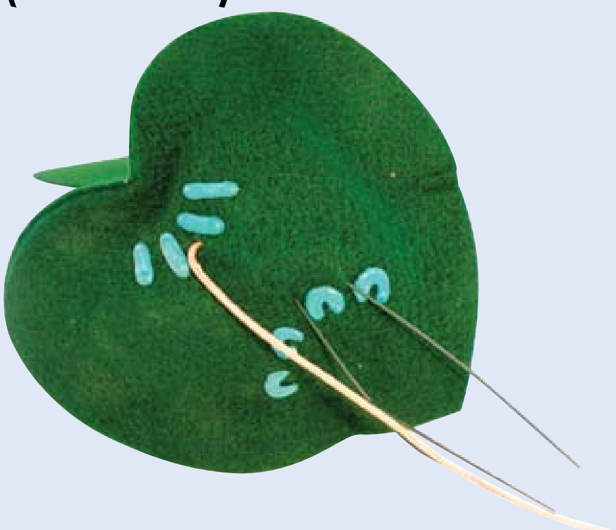

FIGURE 6
Anthrax bacilli among cells.

The puff paint allowed me to show cell boundaries with more definition than regular paint. Figure 6 shows cells from an animal infected with rod-shaped bacteria (*Bacillus anthracis* [anthrax]); my student with visual impairment could feel the nucleus of this animal cell and the bacteria in the interstitial areas.

Conclusion

All of the models presented in this article are simple, affordable, and effective. Commercially produced models that have already been purchased by science departments can be easily modified. With the use of something as simple as puff paint, students can feel some aspects of a model that may otherwise be only visually distinguishable.

These models were so helpful for my visually impaired student that other students asked to use them as well. Since using these models with all students, I have noticed distinct references to the models on many student exams. Realizing that accommodations for one student have benefited hundreds of students was this teacher's greatest lesson. ■

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NSTA connections

For more information on cell function, see the "Cell Structure and Function: The Most Important Molecule" NSTA Science Object. NSTA Science Objects are online, inquiry-based content modules for teachers—and they are free of charge. For more information, visit *http://learningcenter.nsta.org/products/science_objects.aspx*.

Reference

Weld, J., ed. 2004. *The Game of Science Education.* Boston: Allyn and Bacon.