White Board Manipulatives for Teaching Antibody Structure and Function

Mary Emery Vollertsen
Southeast Arkansas College
Pine Bluff, Arkansas

The drawings or image files of antibodies and antigens were all made with Adobe Illustrator®.

Those of us who teach Anatomy & Physiology or Microbiology for nursing and allied health have an interesting challenge. Our students generally arrive with little or no chemistry background. Furthermore, what little they have had may have convinced them that chemistry is both hard and boring. On the other hand, all biology is becoming more and more dependent on and integrated with new findings in genetics, cell biology and physiology that require a little knowledge of biochemistry. Some understanding of biological molecules and how they work is necessary for successful completion of these courses. It appears that part of our job is to help these students develop intuition and an understanding about how biological molecules behave and work—with almost no time in the curriculum to do it. Perhaps one solution is to try to keep integrating how molecules behave throughout the course.

Although the students are bright, ideas of molecular bonding, shape, flexibility, and movement seem hard for them to understand and visualize quickly. As a result, they have little understanding of other structures, like membranes, or of processes, like diffusion. What they have in their textbook may be lovely, but they seem to walk away with a very two dimensional, static model at best. PowerPoint slides don’t seem to help much either. Unfortunately, while 3-dimensional molecular modeling programs might help, most nursing and allied health students generally don’t have either the time or the background needed to use them effectively. Early in both courses, most instructors traditionally spend a little time trying to explore biological molecules and their behavior. Biological molecules will reappear in different contexts many times throughout each course. As educators, we all know this kind of understanding is critical to understanding cell membranes, receptors and many of the more intricate cellular processes and physiology. A more hands-on approach would always be welcomed by the students.

I teach mostly (90-95%) pre-nursing and allied health students in Anatomy & Physiology and also Microbiology. Most of my students are intelligent, caring individuals. Some of them have had limited opportunities for education in the past. Quite a few have commented casually that they do not read by choice or for pleasure. Almost all describe themselves as preferring “hands-on” learning. Many of them have a very strong visual component to their learning as well. They love activities that they can do and objects they can manipulate. They also like to talk about what they are doing or seeing. In the lecture portion of my classes, I use a PowerPoint lecture core on a large TV screen so I can easily show many photographs, micrographs, and drawings, and it is easy to “interrupt” the core with demonstrations or more active learning. I go back and forth between the PowerPoint and the whiteboard repeatedly because I can frequently show processes or answer
questions better on the board. The use of these manipulatives is intended for one of those interruptions.

**Making the Antigens and Antibodies**

A few years ago I found a write-up in the *MicrobeLibrary Curriculum: Classroom* that intrigued me entitled *The Use of Manipulatives for Microbiology and Immunology Students*. In it Beverly Barham (2003) wrote about using manipulatives that were fairly simple shapes cut out of bright poster board and other materials, to teach antibody and antigen assays. To use the manipulatives on a whiteboard, she attached the shapes to magnets so that they could be used to set up the scenarios that she showed in the photographs that accompany her instructions. She shows photos of some of the setups. These looked like they would be student attention grabbers because the manipulatives can be animated in front of them. Students, or groups of students, would also get access to sets of the manipulatives to work through the various processes. (See her informative article and its appendices (which contain photos) for more details of her approach. If you do not have a membership to *MicrobeLibrary*, you will only see the abstract. You may be able to see the whole article using the BEN portal or other portals.)

Since we introduce students to the immune system in Anatomy & Physiology, I wondered if I could use part of this approach to create more interest in a short lesson on understanding antibody molecules. Much is now known about immunoglobulin structure that helps explain the behavior of these molecules. Not only is this information helpful for understanding antigen-antibody reactions, but it also helps reinforce the importance of many of the ideas about biological molecules that we have been trying to teach throughout the entire course.

To implement these goals, I have created images of various antibodies and antigens using *Adobe Illustrator®*. They are contained in the accompanying files. As you will see, these images show the following regions that are critical to an understanding of the function of these molecules: domains, hinge regions, disulfide bond, bonding sites. They can be used to develop large and bright magnetic manipulatives for use on a magnetically responsive white board. The goal of this project is to introduce nursing and allied health students to antibodies, their structures, and how they bind to antigens. If desired, they can be scaled smaller for individual student use.

*Warning: Before making white board manipulatives please do check and make sure the white board you will use allows magnets to stick to it. All the white boards I have tested do, but there are apparently some that do not. Traditional chalkboards will not work. (No magnetic white board? The images can also be glued to felt and used on a felt board. Thank you, Susan Allan, Lone Star College-North Harris in Houston, TX for this last idea.)*

One of the best ways to use the accompanying files would be to create white board manipulatives. That way one can easily add and move images to focus the students’ attention on an object’s interactions. Unlike on a PowerPoint slide, one can also easily add to the story on the white board using colored board markers. The images in the file can easily be blown up fairly large at a copy shop and put onto heavy paper. You might wish...
to laminate them after printing and then attach the images to foam core or poster board so they will last longer and remain clean—the white board markers can get messy! The images can also be made somewhat smaller for students to use at their desks.

The manipulatives need to be stiff enough so that both instructors and students can easily move them on the board. Floppy antibodies aren’t much fun! The flexible magnets that are intended to be used to make business cards magnetic are an easy way to magnetize the manipulatives. Since these magnets are self adhesive, they can be quickly attached to the backing of your manipulatives. One can then attach the cut-out backed image to the white board. Do be careful that the manipulatives don’t become too heavy for the magnets to hold up.

**Materials**

The files of the antibody and antigen images
Printouts of the above files (Images may be scaled and/or laminated.)
Foam core board for backing (Poster board might work too)
Two-sided or double-sided tape and/or glue
Self-adhesive magnetic backing for business cards, or other self-adhesive flexible magnets
Chenille stems (pipe cleaners), or foam covered wire
Utility scissors
“Exacto” knife, if needed

**General Instructions for Creating the Antibodies and Antigens**

1. Print the images to an appropriate size or take them to a copy shop to be printed to larger paper. Card stock is easier to work with than lighter-weight papers. (While more expensive, photo paper will print beautifully and is also thicker.)

2. Student versions could be printed to card stock and cut out of it. The pieces will lay flat on a desk without being backed with heavier backing. If these will be used for several semesters, they, too, will last longer with lamination.

3. If you wish to laminate any images for the white board manipulatives, do so before attaching them to the foam core board or poster board.

4. Depending on the surfaces you are working with, the images can be attached using either double sided tape or glue. If you use glue, be sure to let it dry well before cutting out the pieces.

5. You may be able to cut out the backed images with scissors. I have done this successfully with the thinner types of foam core board. An Exacto knife works well on thicker foam core. Depending on the materials you use, cutting the image together with the base, will probably give the cleanest edges and work the best.
6. You can easily cut flexible self-adhesive magnets with old scissors. Cut appropriately shaped pieces of the magnets and attach them in different spots to the back of each image. You will want to test for the needed amount of flexible magnet on the materials you are using. Be sure that the manipulatives adhere to the board well.

**List of Images and Teaching Notes**

There are quite a few excellent textbooks and websites on immunology. I list a few that I used in the references section. One website that has incredible images of antibody structures is Dr. Clark’s webpage (Clark, 2007).

The following is a list of images with teaching notes to pick and choose among in planning your lesson:

**Simplified Raytraced Images**

These first antibodies are simplified interpretations of Dr. Clark’s Raytraced Image of the Model of Human Immunoglobulin G. (Raytraced images are created on a computer program that creates a type of 3-D image. Dr. Clark’s wonderful image shows details of the protein and carbohydrate make up the molecule.) The first two simplifications of Dr. Clark’s Immunoglobulin G give an overall 3-D feeling for the monomeric antibody molecule. The second two contrast the heavy and light chains.

**Immunoglobulin 1**—contains a 3-D colored interpretation of the molecule as an overview.

**Grey Shaded Antibody**—contains a grayscale version of the above with a slight spacing at the hinge region. The hinge region could be replaced with a chenille stem on each side to allow flexibility of the hinge region on the board. The image could also be enhanced with color pencils.

**Larger Antibody Domains**—contains a colored coded version of the above molecule with the domains of the light chains (red), the heavy chains (blue), and the carbohydrates (yellow) attached to the heavy chains. There is also spacing at the hinge region to show flexibility. Even though it cannot be seen from the model, please remind the students that there is also some flexibility between other domains as well.

**Antibody Complete Domains**—contains a colored version of the above with a front and back to set up a small student sized model. The page includes brief instructions for putting the antibody together on the sheet. For each student model you would need: The page reproduced on card stock, a chenille stem cut into two equal parts each about 5” to 6” long, double-sided tape, and scissors. Remind the students to be sure and overlap the bottom area of the antibody. Since the disulfide bonds are missing that would help hold the antibody stable just before the hinge region, one may need a little tape there to reinforce the integrity of the model.
More Stylized Approaches
(The following files are more traditional stylized approaches to understanding the structures of antibodies and antigens.)

Stylized Antibody and Antigens—contains a highly stylized monomeric immunoglobulin. This one shows heavy and light chains, the variable region on each, the carbohydrate and the disulfide bonds. (Note: to make the model work on paper the disulfide bonds appear different lengths. That is undoubtedly not true in the actual antibody.) This page also contains several antigens. I would glue matching fronts and backs together sandwiching a small piece of magnet in between. That way I would have “complete antigens” to use that are colored on both sides. There are two different styles of antigens as well. This allows discussion of epitopes, specificity, antigen-antibody binding, and affinity.

Epitopes—antigens are too large for the antibody to bind with the entire antigen. The portions of the antigen that the antibody can bind with are called the epitopes or antigenic determinates.

Specificity—the student can easily see that only certain shapes and orientations will fit into the antigen binding sites.

Antigen-Antibody Binding—the lock and key model and the induced fit model are both traditionally used. Some specific antigen-antibody binding is thought to be best explained by the lock and key model. These would have higher affinity. Others are better explained by the induced fit model and would result in a probable lower specificity and affinity. This kind of bonding may also contribute to cross-reactivity of an antibody to other different, antigens. There is also a third more recently proposed equilibrium model that cannot be shown with this antibody as you would need two different isomeric forms (Pier, Lyczak, & Wetzler, 2004)

Affinity—the antigen-antibody bond is the sum of all the noncovalent bonding that takes place between a single active site of the antibody and a single epitope of the antigen. Affinity refers to the total strength of that bond. A stronger bond is more likely to keep the antigen and antibody bound together. The two different shaped antigens allow discussion of this. Clearly, one style fits perfectly at the antigen binding site on the antibody. The other antigen style fits in the antigen binding site but will not allow as tight bonding to the antibody.

The next three files have simpler matching antibodies and antigens. These can be used to discuss the antibody classes and also antibody avidity.

Bacterium and Antibodies—contains a very traditional presentation of a bacterium showing two different stylized epitopes on the antigenic cell wall with smaller highly stylized antibodies to bond with them.

Monomer and Dimer Antibodies and Antigens—contains the same highly stylized antibodies. This sheet contains two monomeric antibodies and one dimeric antibody. The dimeric shows the J chain (green). The page also contains two antigens to go with them.

Pentameric Antibody and Antigens—contains one large pentamer (IgM) of the same style and scale as the previous two files and two antigens. On the image, the disulfide bonds
holding the J chain (green) are longer than they need to be to make it possible to cut out the J chain. Once the J chain is cut out, you may wish to shorten the yellow disulfide bonds that were holding it. Glue the J chain so it slightly overlaps the two adjoining monomer units there.

References


Board of Trustees of the University of South Carolina (2008). University of South Carolina school of medicine microbiology and immunology online. Retrieved June 29, 2008 from http://pathmicro.med.sc.edu/book/immunol-sta.htm (The immunology section alone has 19 excellent chapters, many with video lectures. These are aimed at medical students and assume some science background.)


After Mike Clark’s Raytraced Image of the Model of Human IgG

Immunoglobulin 1

hinge region

2008 MEV
Cut out each side of the antibody. Cut each side of the front apart at the hinge region. Use a chenille stem ("pipe cleaner") about 5" to 6" to replace the hinge. Attach it on the back on both sides of the right front side leaving a little room so the hinge can move. Make the left side the same. Attach the right and left side together at the base of the antibody overlapping slightly. Cut the pieces of the back of antibody apart. Tape them to the corresponding front pieces.

Use double sided tape throughout to attach each piece.

Overlap here

After Mike Clark's Raytraced Image of the Model of Human IgG.
Bacterium with Antigens plus Matching Antibodies
Grey Shaded Antibody

After Mike Clark's Raytraced Image of the Model of Human IgG

2008 MEV
Larger Antibody with Domains

After Mike Clark’s Raytraced Image of the Model of Human IgG

2008 MEV
Monomer and Dimer Antibodies

2008 MEV

J chain
Pentameric Antibody & Antigens

J chain at end of disulfide bonds