Lesson name: Virus Shape and Structure

Grade Level: 9-12

Lesson Description: Students will learn about viruses in general and build 3-D models of icosahedral viruses to understand the use of symmetry in virus assembly. They will read the Molecule of the Month feature on "Poliovirus and Rhinovirus" (RCSB PDB August 2001) to understand viral infection and immunity.

Objectives of lesson:
Students will learn about:

1. Shapes and structures of proteins
2. Viruses: what they are composed of and their life cycle
3. The shapes of viruses and how they assemble
4. Viral infections and immunity

Key Concept:

- Proteins have specific shapes.
- Repeating units of the same protein (or a set of proteins) can create a closed symmetric shape. Viruses are composed mainly of some genetic material (RNA/DNA) enclosed in a protein shell (which is often highly symmetric).
- Viruses have limited space in their genome, so they use symmetry and multiple copies of one or a few types of subunits to create large shells.
- Viruses inject their genetic material into host cells and hijack their cellular machinery for their own propagation.
- Viral infection can be prevented by blocking the entry of its genetic material into host cells.

NJ core curriculum standards addressed by the lesson plan:

- Life sciences: "Matter, energy and organization in living systems", "Diversity and Biological Evolution" and "Reproduction and Heredity"
- Environmental studies: "Natural systems and interactions"
- Mathematical application: "Geometry and measurement" and "Patterns and Algebra"

Time:
50minutes to 1 hour

Materials:
For background, concepts and additional reading:
Computer with internet
RCSB PDB website (www.pdb.org)
Molecule of the Month feature on "Poliovirus and Rhinovirus" and "Bacteriophage phiX174"
Molecular machinery poster (this can be accessed from http://www.pdb.org/pdb/education_discussion/molecule_of_the_month/poster_quickref.pdf)
Additional resources and links listed at the end of the lesson plan
For building 3-D models of viruses:

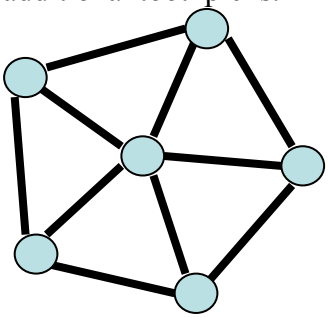
Marshmallows and toothpicks
Printouts of Flattened icosahedral polio virus (PDB ID 2plv), scissors, clear tape
For assessment of students:
Teacher assigned questions (Some possible questions are included here. These may be revised or expanded to meet the needs of the class)

Student assessment:
The 3-D model(s) of icosahedral viruses: should have 20 faces and form a closed particle
A summary paragraph: student should be able to clearly and correctly describe the composition and shape of viruses and how that relates to the 3-D model they created.
They should be able to answer teacher assigned questions demonstrating and understanding of key concepts

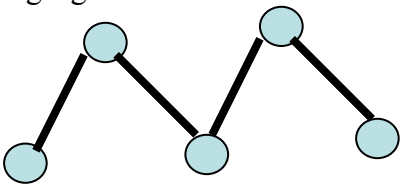
Overview of lesson implementation:
The teacher will briefly introduce students to the shapes of proteins using the Molecular machinery poster available from RCSB PDB. This can be followed by an introduction to viruses in general: their composition, life-cycle, shapes and sizes. Since viruses have very small genomes they utilize symmetry to create the protein shells in which they package their genetic material. The teacher can show students the icosahedral shape and demonstrate how to make 3-D virus models. The students then make the 3-D virus models in class and write a paragraph describing it. As a homework assignment, students can read the Molecule of the Month features on "Poliovirus and Rhinovirus" and "Bacteriophage phiX174" and answer the teacher assigned questions.

Instructions for building 3-D icosahedral virus models:

The marshmallow model
Start with a marshmallow and attach 5 toothpicks to it like spokes of a wheel. Now attach 1 marshmallow to each open end of the 5 toothpicks and connect adjacent marshmallows with 5 additional toothpicks. The resultant model should look as follows:

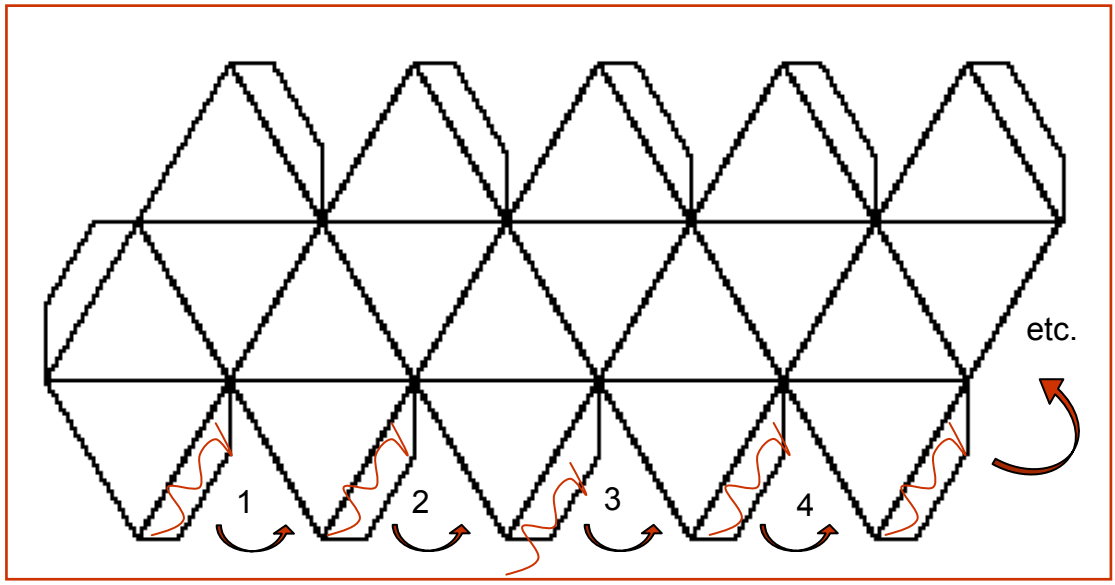


Make 2 such models to form the top and bottom pentagons. Now connect the 2 pentagons in a zigzag manner as follows:



The paper model

Cut out the flattened virus model (of 2PLV, attached) and fold along all the links in the cutout. Start making the closed model by taping together the red shaded flaps under the adjacent edge as shown below:



Continue taping the edges till you can close the icosahedral virus.

Sample questions to answer:

1. How many edges does the icosahedral virus have?

Answer: 30

2. How many vertices does the icosahedral virus have?

Answer: 12

3. Mark the 5, 3 and 2 fold centers on the model.
4. What is the function of the icosahedral shape that you modeled in relation to viruses?

Answer: The icosahedral shell is used as a shell to package the genetic material. This also has proteins which bind to host cell receptors, which is the first step for viruses to attach to host cells and inject its genetic material

5. Name 5 different icosahedral viruses that you can find in the PDB?

Answer: rhinovirus, poliovirus, dengue virus, tobacco ringspot virus, turnip yellow mosaic virus.

6. What is the genetic material in viruses?

Answer: It can either be DNA or RNA depending upon the type of virus.

7. How do viruses replicate?

Answer: Viruses hijack the host cell machinery to duplicate their genetic material. Some viruses may have special enzymes that they carry to help in this process. Viruses also use the host cell's protein production machinery to make multiple copies of their coat proteins. The coat proteins assemble into the icosahedral shells and the genetic material is packed in it. When many copies of the virus are made, the host cell usually breaks open to release the newly made virus particles.

8. Aside from icosahedrons, what other symmetric shapes do viruses have?

Answer: Helical

9. How do vaccines and common antiviral agents work?

Answer: Vaccines prompt the generation of antibodies that bind to specific portions of the icosahedral shell of the virus. This coating prevents the virus from binding to host cells and blocking infection. Many common anti-viral agents (drugs) also work at the same step. They bind to the icosahedral shell at places where the host cell receptor would bind, thereby preventing infection.

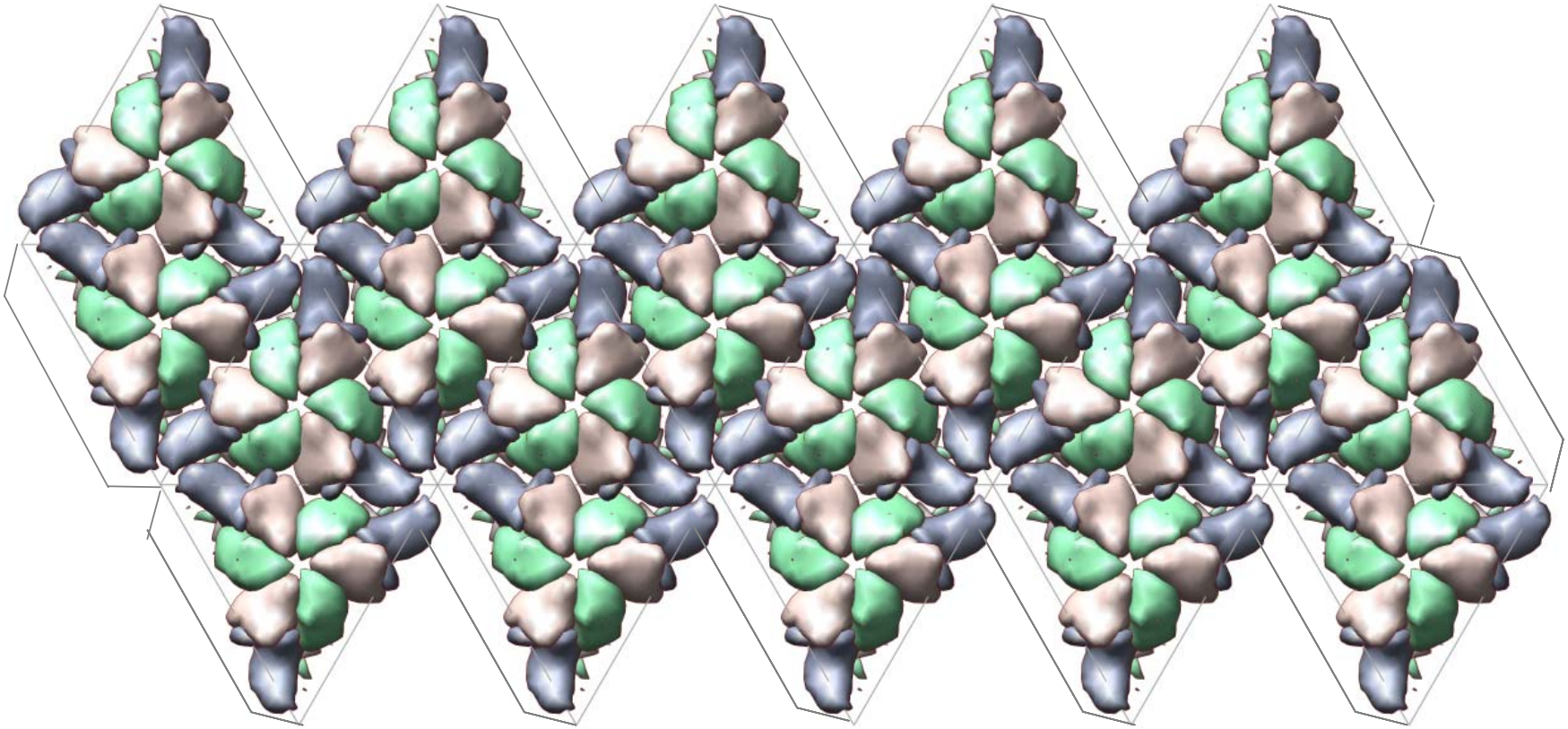
10. Why do some vaccines such as polio, last you a lifetime while you have to take flu shots every year?

Answer: The difficulty of creating a vaccine for the common cold lies in the diversity of rhinovirus. Over one hundred types of rhinovirus have been discovered as they strike people around the world, and new strains appear continually. Rhinovirus is a moving target that is not effectively combated with a single vaccine.

Additional resources:

http://viperdb.scripps.edu/
http://virologyhistory.wustl.edu/
http://web.uct.ac.za/depts/mmi/jmoodie/welcome1.html

Polio Virus (2plv)



Structural factors that control conformational transitions and serotype specificity in type 3 poliovirus. EMBO J. 1989 May;8(5):1567-79.

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