BioEd℠ Teacher's Guide

the science of HIV/AIDS

Modeling an HIV Particle

Portrait of a Killer

by

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RESOURCES

Free, online presentations, downloadable activities in PDF format, and annotated slide sets for classroom use are available at www.bioedonline.org or www.k8science.org.

CONTENT ADVISORY

See the following resources for additional information about HIV/AIDS and advice for discussing HIV/AIDS with students.

- National Institute of Allergy and Infectious Diseases, National Institutes of Health (NIH), offers resources on understanding HIV/AIDS: niaid.nih.gov/topics/hivaids/and aidsinfo.nih.gov.
- National Institute on Drug Abuse, NIH, offers facts about drug abuse and the link between it and HIV/AIDS: hiv.drugabuse.gov.
- The Centers for Disease Control and Prevention provides up-to-date information on HIV/AIDS prevention: cdc.gov/hiv/topics.

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SOURCE URLs

AMERICAN DENTAL EDUCATION ASSOCIATION
explorehealthcareers.org

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BIOED ONLINE TEACHER RESOURCES
bioedonline.org | k8science.org
BAYLOR-UT CENTER FOR AIDS RESEARCH
bcm.edu/cfar
MOLECULAR VIROLOGY AND MICROBIOLOGY
bcm.edu/molvir

DARTMOUTH COLLEGE
ELECTRON MICROSCOPE FACILITY
dartmouth.edu/~emlab/

THE HENRY J. KAISER FAMILY FOUNDATION
kff.org

JOURNAL OF NANOBIOTECHNOLOGY
jnanobiotechnology.com/content/3/1/6

NATIONAL INSTITUTES OF HEALTH
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science.education.nih.gov/lifeworks

NATIONAL CENTER FOR RESEARCH RESOURCES
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NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES
www.niaid.nih.gov
aidsinfo.nih.gov
NATIONAL INSTITUTE ON DRUG ABUSE
hiv.drugabuse.gov
NATIONAL LIBRARY OF MEDICINE
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SUMANIS, INC.
ANIMATED TUTORIALS: MICROBIOLOGY
http://sumanasinc.com/webcontent/animation.html

U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION (CDC)
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cdc.gov/hiv/topics
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THE WORLD FACTBOOK
https://www.cia.gov/library/publications/the-world-factbook/geos/us.html

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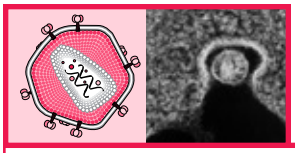


HIV virus particle. Charles P. Daghlian, Ph.D., Louisa Howard, Dartmouth College.

INTRODUCTION

Microbial Challenges

Infectious diseases have plagued humans throughout history. Sometimes, they even have shaped history. Ancient plagues, the Black Death of the Middle Ages, and the "Spanish flu" pandemic of 1918 are but a few examples.

Epidemics and pandemics always have had major social and economic impacts on affected populations, but in our current interconnected world, the outcomes can be truly global. Consider the SARS outbreak of early 2003. This epidemic demonstrated that new infectious diseases are just a plane trip away, as the disease was spread rapidly to Canada, the U.S. and Europe by air travelers. Even though the SARS outbreak was relatively short-lived and geographically contained, fear inspired by the epidemic led to travel restrictions and the closing of schools, stores, factories and airports. The economic loss to Asian countries was estimated at $18 billion.

The HIV/AIDS viral epidemic, particularly in Africa, illustrates the economic and social effects of a prolonged and widespread infection. The disproportionate loss of the most economically productive individuals within the population has reduced workforces and economic growth in many countries, especially those with high infection rates. This affects the health care, education, and political stability of these nations. In the southern regions of Africa, where the infection rate is highest, life expectancy has plummeted in a single decade, from 62 years in 1990–95 to 48 years in 2000–05. By 2003, 12 million children under the age of 18 were orphaned by HIV/AIDS in this region.

For an emerging disease to become established, at least two events must occur: 1) the infectious agent has to be introduced into a vulnerable population, and 2) the agent has to have the ability to spread readily from person to person and cause disease. The infection also must be able to sustain itself within the population and continue to infect more people.

Despite significant advances in infectious disease research and treatment, control and eradication of diseases are slowed by the following challenges.

- The emergence of new infectious diseases
- An increase in the incidence or geographical distribution of old infectious diseases
- The re-emergence of old infectious diseases
- The potential for intentional introduction of infectious agents by bioterrorists
- The increasing resistance of pathogens to current antimicrobial drugs
- Breakdowns in public health systems.

Baylor College of Medicine, Department of Molecular Virology and Microbiology, bcm.edu/molvir.

Using Cooperative Groups In The Classroom

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. Suggested job titles and duties follow.

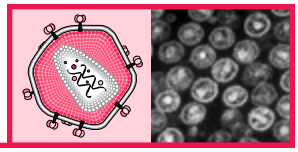
Principal Investigator
- Reads the directions
- Asks the questions
- Checks the work

Maintenance Director
- Follows the safety rules
- Directs the cleanup
- Asks others to help

Reporter
- Records observations and results
- Explains the results
- Tells the teacher when the group is finished

Materials Manager
- Picks up the materials
- Uses the equipment
- Returns the materials

* Jones, R.M. 1990. *Teaming Up!* LaPorte, Texas: ITGROUP.



HIV-1. CDC\ 948 Edwin P. Ewing, Jr., Ph.D., Carey S. Callaway.

Portrait of a Killer

IMAGINE YOU ARE A DOCTOR...

A young man arrives at your hospital in a very weak, deteriorated condition. His body resembles that of a concentration camp survivor. After running a few tests, you determine the patient is suffering from pneumocystis pneumonia, a very rare lung infection, especially in people with healthy immune systems. As a doctor, you refer to the infection as PCP. Over the coming weeks, several more patients arrive at your hospital, suffering from the same condition. All eventually die. You infer that every recent PCP patient had a weakened immune system.

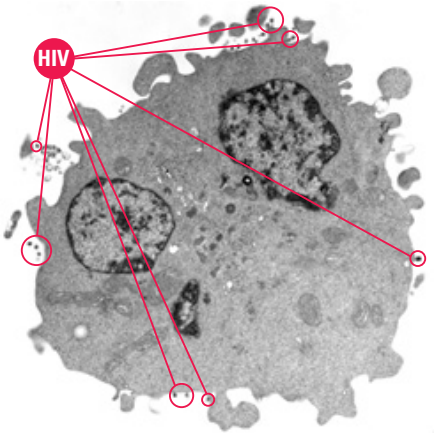
A cluster of patients with the same rare condition raises a medical "red flag." Something new may be happening.

Across the country, other doctors encounter larger than the usual numbers of PCP patients, and other people with a different rare disease, Kaposi's sarcoma (or KS). KS is a form of cancer. It causes purple, red, brown and black skin lesions (sores) to appear over the entire body and in the mouth. The lesions are painful and disfiguring. They make eating difficult, and often are accompanied by unrelenting headaches. Ultimately, the KS patients die. Like PCP, Kaposi's sarcoma is exceedingly rare in people with healthy immune systems. Doctors treating KS patients infer that these people had weakened immune systems.

This really happened. The first recognized cases of the syndrome we today call AIDS, or acquired immunodeficiency syndrome, appeared in homosexual men in California in 1981. Soon after, similar clusters of AIDS cases occurred in New York. Then, men and women of Haitian origin began checking into Miami hospitals with symptoms of both PCP and KS. They, too, had AIDS, which was spreading across the country. It is estimated that by the time of its discovery, the new virus called HIV already had infected hundreds of thousands of men, women and children in the United States, and millions more people around the world.

WHAT IS HIV?

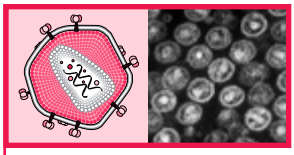
In the strictest sense, HIV, the Human Immunodeficiency Virus, is not a life form. Until it invades a human host, it's just a protein-coated mass of genetic material, no more alive than a grain of sand. Under a microscope, HIV appears insignificant, approximately 120 times smaller than the white blood cells it invades. But it is frighteningly powerful. Once inside a cell, HIV's genetic material serves as a biological "how-to" manual. The virus replicates itself hundreds of thousands of times, until the cell can no longer contain all the individual viruses. The new viruses push out, or "bud," through the cell wall. In the process, they steal part of the cell's outer envelope (cell membrane), which they use to create an outer protective layer.



This is a blood cell infected with HIV. Notice how tiny the HIV particles are compared to the cell!
Photo: Charles P. Daghlian, Ph.D., and Louisa Howard, Dartmouth College.

Over a period of years, new HIV copies spread through the host body to infect more and more cells.

Gradually, the body's white blood cells, the "backbone" of a person's immune system, are destroyed. When the immune system is working, it attacks and fights off invading diseases. But when it is weakened or destroyed, it can no longer protect the body. Ultimately, HIV infection leads to a condition called AIDS, or acquired immunodeficiency syndrome. Untreated, AIDS opens the body to progressively rare and devastating illnesses until death results.



HIV-1 particles. CDC:1948 Edwin P. Ewing, Jr., Ph.D., Carey S. Callaway.

TIME

Setup: 20 minutes
Activity: 1–2 class periods

Overview

Students will learn about the basic structure of the human immunodeficiency virus by constructing three-dimensional paper models of an HIV virus particle.

MODELING AN HIV Particle

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- Disease is a breakdown in structures or functions of an organism. Some diseases are the result of damage by infection by other organisms.
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to the next.

Grades 9–12

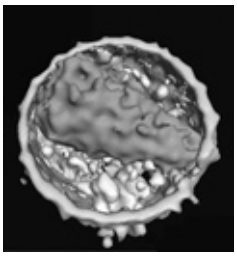
Life Science

- In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA [usually], a large polymer formed from subunits.
- Cells store and use information to guide their functions.

CITATIONS

Image citations, including source URLs, are available at the front of this guide.

This activity will help students visualize the Human Immunodeficiency Virus (HIV) by having them construct 3D HIV particle models from paper. The model to be used represents a complete viral particle.



The capsid surrounding the RNA-containing core of an HIV particle is revealed using Cryo-electron tomography (left). Photo: Stephen Fuller © Wellcome Images\B0006824.

It is a 20-sided polyhedron, called an icosahedron, which approximates the shape of the virus. The completed, three-piece model is about 500,000 times larger than an actual HIV virus particle. Students will combine their finished models into one mass in a first step toward estimating how many HIV particles could be contained inside a white blood cell before being released into the blood stream to attack new cells.

MATERIALS

Per Student

- "Modeling an HIV Particle" sheet printed on white card stock paper
- Scissors
- Cellophane tape (one roll can be shared by two or three students)
- Metric ruler with straight edge
- Fine point ballpoint pen with which to score cardstock before folding (felt- or gel-tipped pens are not appropriate)
- Colored markers or pencils for coloring the models (not crayons)

SETUP

Make enough copies of the HIV particle model on card stock paper for each student. Make a few extra copies to use as "spare parts" and for demonstration. (Teacher Tip: You may wish to enlarge the cutout of the virus model for demonstration purposes.) Have students work together in groups of 2–4 to assist each other, especially during model assembly and taping. Each student should make his or her own virus model.

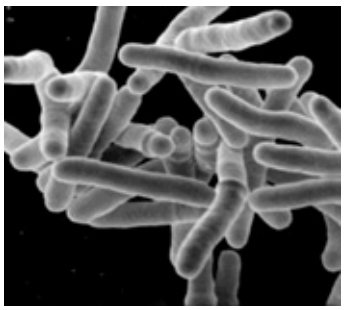
PROCEDURE

1. Ask students, *Have you ever seen a virus?* [It is not possible to observe viruses directly, because they are extremely small.] Encourage students to share what they already know about viruses. List their ideas on the board. Make sure that the following facts are included.
   - Viruses are small infectious agents that require living cells to make copies of themselves (replicate)
   - Viruses replicate by invading living cells
   - Most viruses are too small to see with a microscope
   - Viruses are responsible for many different diseases,

BACTERIA AND VIRUSES

Viruses, the tiniest microbes, must be magnified about 150,000 times to be seen. They are not considered cells, because they do not have cell walls, cell membranes or nuclei. They also cannot grow or reproduce on their own. Instead, as described above, they invade healthy cells in living organisms and force these cells to produce more viruses. This is how viruses, such as HIV, cause disease. Antibiotics, which are effective against bacteria, cannot destroy viruses.

Bacteria are minute, single-celled organisms much larger than viruses. (Most bacteria must be magnified about 1,000 times to be visible.) Bacterial cells have DNA, a cell membrane and usually a cell wall, but they do not have defined cell nucleus. Some bacteria are capable of movement, and many are valuable as recyclers in ecosystems. Other bacteria have chlorophyll and carry out photosynthesis. Bacterial infections can be treated with antibiotics, but some bacteria have become resistant to common antibiotics.



TB is a disease caused by the bacterium called *Mycobacterium tuberculosis*. The disease mostly affects the lungs. People with weakened immune systems, such as from AIDS, are not able to fight the TB bacteria and ward off infection.
Photo: Rocky Mountain Laboratories, National Institute of Allergy and Infectious Diseases, NIH\Clifton E. Barry, III, Ph.D. Barry, Elizabeth R. Fischer.

including the common cold, flu, small pox, and HIV/AIDS
- All viruses consist of genetic material (DNA or RNA) surrounded by a protective coat.

2. Discuss the purpose of the activity with your students. They will learn about the Human Immunodeficiency Virus (HIV) by constructing a paper model that enables them to visualize a single HIV particle. The model will show both the exterior and interior of the particle and serve as a starting point to learn about the virus's function.
3. Demonstrate how to cut and fold the model. Stress that the more carefully students cut out their models and score the folds, the better the models will look. Students should cut along the solid lines and use the ruler straight edge and ballpoint pen to score the dashed fold lines. Pressing the pen tip into the paper produces a crease that makes accurate folding easy.
4. Have students color their models prior to assembly. While virus particles do not have color, researchers often create colored models to emphasize certain structures. [See the presentation "Viruses (NCMI)" on BioEd Online, www.bioedonline.org, for examples of virus models.]
5. Demonstrate how the virus envelope is formed. Start by creasing along the edges of each triangle, and then reopening the creases. Begin taping with two adjacent triangles. Bring their adjoining straight edges together and hold with a small piece of tape. Continue taping triangles until the model gradually forms a spherical shape. Repeat until all triangles but one are taped together. The remaining triangle serves as a "door" to the inside of the virus.
6. Have students follow the same cutting, folding, and taping procedures for the HIV capsid. They also should press the capsid insert into the capsid. If the insert is loose, a small dab of glue or a small reversed tape ring will hold it in place. Temporarily slip the capsid inside the model.
7. Discuss the model's appearance and structures as a class. Explain that the model is approximately 500,000 times bigger than an

Continued

MICROBES AND DISEASE

Organisms that cause diseases are called "pathogens," from the Greek word pathos, or suffering. Most pathogens are microbes, such as bacteria, viruses or fungi (such as yeast). Sometimes, we call these tiny pathogens "germs."

Not all microbes cause diseases. Many microorganisms, like the bacteria in our digestive systems or photosynthetic algae in the oceans, are helpful. Further, not all illnesses are caused by microbes. For example, diabetes, heart disease related to atherosclerosis, and some kinds of cancer are not believed to be caused by infections.

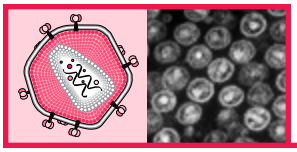
NANOMETERS

To compare the size of an HIV particle to other objects, divide the size of each object below by 120 nm (the size of one HIV particle).

- **Visible light wavelength:**
  400 to 700 nm
- **Human hair:**
  100,000 nm wide
- **Period on a page:**
  500,000 nm
- **Penny:**
  19,000,000 nm wide
- **Basketball:**
  239,506,000 nm wide

actual HIV particle. Ask, *How big do you think the actual HIV particle is?* [about 120 nanometers] List a few comparisons, measured in nanometers, for visualization (see "Nanometers," left sidebar). A nanometer is one one-billionth of a meter (approximately 0.04 billionths of an inch). Ask, *How tall are you in nanometers?* [Your height in meters times one billion.]

8. Have each student measure the diameter of his/her virus model. Ask, *Since the model is not a sphere, what is the best way to measure it?* Discuss different ways to measure the model's diameter (point to point, point to side, edge to edge, side to side).
9. Tell students that the white blood cell invaded by the HIV particle is 120 times larger than the particle. Ask, *Compared to the HIV model, how big is a white blood cell?*
10. Have all students place their HIV models into a pile to see how large the mass of models becomes. Count the number of particles in the pile. Then ask, *How many HIV particles do you think it would take to fill a white blood cell? How could you find out?* (It would take about 1.7 million HIV particles to fill one white blood cell completely. This calculation is based on a comparison of the volume of an HIV particle with that of a white blood cell. To compute these values with students, use the equation, volume = $4/3\pi$ radius^3.
11. Have students collect their HIV virus particle models and save them for use in the "Making Copies of an HIV Particle" activity.

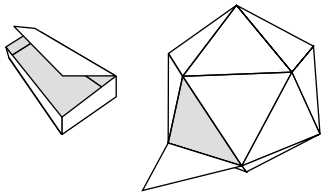


Modeling an HIV Particle

HIV-1 particles. CDC\ 948 Edwin P. Ewing, Jr., Ph.D, Carey S. Callaway

INSTRUCTIONS

1. Carefully cut out the Viral Envelope and Capsid pieces along the outer, solid straight lines.
2. Use markers or pencils to color the pieces.
3. Score and fold along the dotted lines.
4. Use small pieces of tape to join edges together **EXCEPT** where indicated. Assembled part shapes are shown below.



5. Cut out the Capsid Genetic Material piece and insert it into the Capsid. Close the flap.
6. To complete the model, insert the Capsid into the Viral Envelope and close the triangular "door."

VIRAL ENVELOPE

Outer surface of particle (circles represent spikes)

CAPSID GENETIC MATERIAL

Two identical strands of RNA, and enzymes, including reverse transcriptase

CAPSID (Internal Core)

Contains genetic material

Illustrations by G.L. Vogt and M.S. Young © Baylor College of Medicine