Yale-New Haven Teachers Institute®

Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2015 Volume IV: Big Molecules, Big Problems

Introduction

Explaining the unseen. This is what lies at the root of teaching students about the molecules of life. Skin is elastic at birth, wrinkled and inflexible when we are old. The collagen that is responsible for this is a big molecule, yet still too small to see. Insulin made by the pancreas in your abdomen finds its way to your arm, signaling the tissue to take up any sugar that comes its way. Insulin is also big, yet too small to see. The approach of the "Big Molecules, Big Problems" seminar was to visit one after another amazing molecular machine and break it down into a discussion about the same small set of simple parts and the same small set of simple forces that govern them.

From the top of a mountain looking to a village below, students can't see a brick. But they can see a house made of brick, a bridge, a garden path or a bridge. Bridges are not houses, but students can study all these different structures and eventually see how they might be all be made from these invisible bricks. They can understand bricks even if they never come down from the mountain.

Participants began the seminar by learning the computer skills necessary for looking at the known atomic structures of proteins and DNA. Thousands of such structures have been solved by scientists. For the seminar, we came back to this visualization tool at almost every session regardless of what we were talking about that week. Our first set of big molecules was antibodies. We looked at atomic structures where two different antibodies attached to different sides of one protein target. We also looked at the atomic structures of two antibodies that were different, and you could attach to the same location on the same protein. Just imagine having two different keys for the same lock! These and other features had to be understood at the molecular scale to discuss how a home pregnancy test works. The seminar explored many other problems and challenges that big molecules have solved – for example, a protein that makes a pore that allows water and not hydrogen through it. Then we looked at a protein that makes a pore that lets hydrogen through but not water. Anyone can make a hole for a tennis ball that will keep a basketball out. Big molecules can make holes for a basketball and that keeps tennis balls out. Try that with plywood and a hole cutter!

As the seminar evolved we took some excursions to some big molecules making big news: Alzheimer's, cancer, sequencing all of your DNA and CRISPR/Cas9. We discussed how the coming CRISPR/Cas9 revolution might save us all. Perhaps instead it will kill us all. The seminar started with the basics: Scientists motivated only by curiosity were studying what many thought was just an unused area of a bacterium's DNA. Turns out, the DNA was part of a big molecular machine the bacterium used to ward off infections from viruses, but only if it or its parents had encountered it before . . . and survived. It seems that even bacteria have an immune system and can be immunized. One step at a time, we discussed how this machine could be taken from bacteria and put into most any organism to change its DNA code. One day it will save millions of lives and

improve the quality of life for countless others. Or one day it could be used to make genetically modified children, just the way you want them. Or one day, it will allow a government to create diseases that only infect and kill its enemies. These grand hopes and fears litter the popular press, and we discussed how the CRISPR/Cas9machine might actually be able or not be able to do these things. Finally, we ended our seminar with a field trip to the Yale Medical School to visit the laboratory of Professor Chuck Sindelar. Professor Sindelar is one of the scientists who has the tools and expertise to look at and solve the atomic structures of these big molecules.

The seminar was informed by resources including popular articles (from the *Atlantic* and *BBC News* to the *New York Times* , *Huffington Post,* and *Wired*), online videos, and peer-maintained *Wikipedia* entries on very current scientific and technological developments. For example, selections from the latter considered such matters as Aquaporin, Oncogene, Polymerase Chain Reaction, Protein Folding, and Sanger Sequencing.

The discussions produced a very diverse set of units. Rebekah Laudermilch has put together a unit with focus on the forces that attract and repel and bond molecules together. A series of progressively more challenging activities culminate in an individualized big molecule project focused on the natural and synthetic polymers that are used to make textiles. Andrea Zullo developed a unit on non-infectious diseases. After studying infectious disease, the concept that disease could be something caused by the body's own failings is a challenging one for students. Her unit breaks down diverse diseases, into different classes of error in surveillance. The body has many large molecule tools that keep a watchful eye on problems. They don't always work, and they don't work forever. Amanda Weires' unit breaks down large molecules into the constituent parts that attract or repel one another. As she is a teacher in an arts-focused high school, she developed her unit around plant oils which get used as binder in oil-based paint. The chemistry of making soap from plant oils versus making paint are put side by side to give a rounded understanding. John Adamovich's unit compares sugar and artificial sweeteners. Students learn to meaningfully assess the nutritional content of food as it relates to sugar. Matthew Eveleth's unit takes on complex ideas in chemical reaction kinetics including enzyme kinetics. Embracing his role as a chemistry teacher at a health and sports-medicine-oriented high school, he uses a creative mix of baseball analogies to keep this challenging material lively. Sheila Martin-Corbin developed a unit to teach aspects of infectious disease. Her class activities place particular emphasis on the spread of disease, and a demonstration of how the herding effect in vaccination works.

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