POLYMER BASICS

Many common items can be used to demonstrate the structure of a polymer.

1. **Paper clips** hooked together in a chain can be used to simulate the way that monomers link up to form very long chains. You can even simulate the process of polymerizing by placing a few “PC” (paper clip) monomers into a container (with a screw-top lid), in which you have already placed a large number of clips hooked together to make a chain. You can simulate the addition of energy, which is necessary to begin the polymerization process, by shaking the closed container. Then you can remove the entire polymer (paper clip) chain; however, it is probable that, when you pull out the chain, you will have short branches of clips extending off the main, long chain of paper clips, and some unlinked (monomer) molecules in the bottom of the reaction vessel. In real polymers, the length of the entire chain helps to determine the polymer’s properties. The important points in this simulation are:
   a. A polymer chain is made up of a repeating monomer unit (the paper clip).
   b. The number of monomer paper clips in this chain is far smaller than the number of monomer units in a useful polymer.
   c. Producing a polymer doesn’t always give a single long chain, but it produces chains with side branches, and frequently leaves some monomer molecules unreacted.

2. **Strands of beads** (costume jewelry) can also represent a chain of monomers. This long strand will usually emerge from a container as a single chain, with few entanglements and side-branches. One extra use of this analogy is to demonstrate auto-siphoning; you must prepare the chain by carefully arranging the beads in the container in a continuous single strand, starting at one end and laying the chain into the container in a layered fashion. Then allow a short segment of the chain to hang down over the side of the container. If it is long enough (roughly one container-length), the entire chain will tumble out of the container. This illustrates the same peculiar property (auto-siphoning) shown by several very long-chain polymer substances.

   **Steel chain** has the added advantage of being attracted to a magnet. This allows you to simulate the effect of adding borax solution to polyvinyl alcohol or to Elmer’s glue — the borax acts as a cross-linking agent and forms bonds between segments of the polymer chains. This makes the previously liquid substance behave as a viscous gel, aka “slime or “Gluep”. The magnet, when placed in the middle of the pile of chain, will attract the rest of the loops of chain close to it, causing it to be much more solid-like than before, simulating the cross-linking bonds that form between the borax and the polymer.

   **Pop beads**, once a rage in the 50’s, are also a useful product to simulate polymers. Different-colored beads can be used to introduce the idea of a co-polymer, one that has two monomers. The monomers can either alternate single monomer units (called, “A-B” copolymer) or alternate groups of monomers (random or block copolymers). Also, the larger size of the pop beads (compared to the steel bead chain) makes the self-siphoning demonstration much more easily observable for a class.

Prepared by William Bleam, Jr., Polymer Ambassador for Pennsylvania, Emeritus
For the NSTA National Convention, San Diego, CA, 3/27-3/30, 2002
3. **Clothes pins** can be used to show many of the same properties as the other aforementioned items. With clothes pins you have the added advantage of being able to show students that the clothes pins can be thought of as being difunctional — having a reactive site at both ends of the clothes pin. When one reacts, the other one is still intact to react again. No matter how many monomers link together, at each end is yet another reactive site to react again. In this way, a polymer can grow to be hundreds of thousands of monomers long. The process will continue to grow an ever-larger polymer molecule until the chemist adds a chemical to bond with those ends of the huge chain and stop the chain growth.

4. At the elementary levels, a commercial toy/game called, **Barrel of Monkeys** uses this concept of difunctionality. Each little monkey in the barrel has its two arms extended, their hands forming little hooks. The goal of the game is to hook the monkeys together as you extract them from the can to get the longest continuous chain of monkeys — just like a polymer in real life.

5. Perhaps **cooked spaghetti** is more like a polymer (and also messier!) than any of the above analogies. The spaghetti has many long strands, all interwoven. These entanglements more closely resemble the interactions of polymer chains, resulting in polymer properties like flexibility and elasticity. The bead chains can also be used in a similar manner if you simply pick up a mass of the chain and allow the long strand to weave back on itself repeatedly, rather than stringing it out in one long strand.

6. The **“Poly People Activity”** is a way to get students actively involved in the lesson. Students actually join hands/arms to link up in much the same way that actual polymers form from monomers. If you begin by linking just two students, they form a “dimer”, two monomers joined. If you continue in this fashion, you build trimers, tetramers, etc. Eventually they form a chain long enough to be considered a useful polymer, one that has properties that allow it to be processable into useful products. You can show how flexibility decreases with increased numbers of people in a chain, just as flexibility decreases with increased chain length in real polymers. Allow the dimers and trimers that have formed in the early stages of the exercise to “flow” freely, to roam about the room. Then link several of the groups together and ask them to roam independently. They have a much more difficult time as the chain length increases. This corresponds to an increase in rigidity of the polymer.

One drawback to any of the simulations mentioned in this paper is that one never gets the chain long enough to truly represent the length of an actual polymer molecule. A hundred, or even five hundred, do not begin to represent the numbers of monomers in a polymer chain. To form a processable plastic requires thousands, tens of or even hundreds of thousands of monomers in the chain.

Another drawback is that none of these show interactions between strands or parts of strands that overlap each other. Branching and cross-linking are common in polymers, but not in simulations. These two factors, along with the length of the polymer chain, contribute significantly to the physical characteristics of the specific polymer.

Prepared by William Bleam, Jr., Polymer Ambassador for Pennsylvania, Emeritus
For the NSTA National Convention, San Diego, CA, 3/27-3/30, 2002