Activity: Molecular Spaghetti

FOR THE TEACHER

Summary
In this activity, students will discover how the entanglement in cooked spaghetti depends on the length of the spaghetti strands and relate this discovery to polymeric materials.

Grade Level
High school

Objectives
By the end of this lesson, students should be able to

- define polymer as a huge molecule comprising repeated molecular sub-units known as monomer.
- state that properties of polymeric materials are a direct result of the entanglement of these huge molecules.
- recognize that differences between different types of polymers arise from differences in the details of the molecular structure.

Chemistry Topics
- Polymers
- Monomers
- Molecular Structure

Time
Teacher Preparation: 60 minutes
Lesson: One class period

Materials
- quart-size bags of cooked spaghetti—one bag of “normal” spaghetti and one bag of short pieces of spaghetti (see preparation details in Teacher Notes)
- two disposable plates for each student group
- One ruler per group

Safety
- Food in the lab should be considered a chemical not for consumption.
- Pick up any noodles that fall to the floor.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials.

Teacher Notes
- Prepare cooked spaghetti prior to class in two batches: normal length noodles and noodles broken into short pieces. To prepare the broken noodles, the uncooked spaghetti can be put into a one-gallon Ziploc bag before breaking to contain the pieces that tend to shoot away when broken. Break the uncooked spaghetti into pieces about 3-5 cm long on average, about 1/5 the length of a typical piece of spaghetti. Prepare the spaghetti
according to package directions. Be sure to use plenty of water and stir the spaghetti well to prevent clumping. Avoid overcooking, as this leads to sticky pasta. After cooking each batch, drain and rinse with water to remove starch on the surface. Separate the batch into portions depending on the number of student groups in your class and place into Ziploc bags for storage. Portion sizes of about 250 mL (about a cup) are adequate. The bags should be refrigerated for storage and brought to room temperature or warmed slightly before class. If the pasta seems to be sticky prior to class use, add drops of vegetable oil as needed to the package.

- In lieu of spaghetti, other models that could be used include string, strings of beads, yarn, etc. The key feature is that the model includes one thin component that is very long and one component that is very short; both components should be otherwise identical.

Cross-Disciplinary Extensions

Connect to Math
Molecular weight averages: Students could learn about different molecular weight averages by combining a sample of long and short spaghetti and measuring the average mass per strand two ways. In the first way, the student grabs a sample of the mixture, masses the sample, and divides by the number of strands. In the second method, the student closes her eyes and grabs strands from the mixed sample, then averages their mass as before. The results should be different between the two methods because short and long chains are equally likely to be picked in the first method, while longer chains are more likely to be picked in the second method. A discussion of sampling would be appropriate here.

Connect to Reading and Writing
As a follow-up, students can conduct research on plastic recycling: what are the benefits and what are the disadvantages, why is it necessary to segregate different types of plastic, how widespread is plastic recycling, are there regional or national differences in recycling rates, etc.

Connect to Social Studies
What is the impact on society from the widespread use of plastics? Are plastics made from renewable resources practical in modern use? Why or why not?

Selected Hyperlinks
The links below give more information on the nature of polymers, using the “spaghetti” analogy.

Carnegie Mellon University: Introduction to Polymers
Science Buddies: Putty Science
Benjamin-Mills: Some important polymers: introductory data

FOR THE STUDENT
Lesson

Molecular Spaghetti

Background
Polymers are an important class of materials that appear in every aspect of your daily experience. All plastic materials are polymers; so, too, are the molecules that make up the textiles you are wearing. Proteins, DNA, cellulose, and starch are examples of naturally occurring polymers. All of these materials share common physical properties, which in turn arise from a common molecular feature.
**Problem/Objective**
In this activity you will explore a model for polymeric materials that will help you to understand the relation between polymer properties and molecular structure.

**Pre-lab Question**
1. List some words you know that begin with the prefix *poly*- . What do you think this prefix means?

**Materials**
- Bag of cooked spaghetti with normal length strands of pasta
- Bag of cooked spaghetti with shortened length strands of pasta
- Two disposable plates
- Ruler

**Safety**
- Food in the lab should be considered a chemical not for consumption.
- Pick up any noodles that fall to the floor.
- Wash your hands thoroughly before leaving the lab.
- Follow teacher instructions when cleaning up materials.

**Procedure**
1. Obtain the two bags of cooked spaghetti from your teacher. Carefully dump the contents into separate piles on disposable plates.

**Exploring Flow Properties**
2. Holding your thumb against your fingers to make a small “tube” (Figure 1), push all of the spaghetti from the normal length pasta sample through the tube with your fingers. Take note of the ease with which each length of spaghetti moves through the tube. Record your observations in table 1 below. Return the spaghetti to a pile.

![Figure 1](image)

3. Repeat step 2 with the shortened length spaghetti noodles.

**Exploring Strength Properties**
4. Working with the normal length pasta first, pinch the end of a strand of spaghetti on one side of the plate with one hand. At the same time, using...
your other hand pinch the end of one strand of spaghetti on the other side of the plate.

5. While pinching the ends of these two strands, and without moving your hands, a group member should measure the distance between your hands and record the length (in centimeters) for “initial separation” in table 2.

6. Next, gently pull your two hands apart until the spaghetti you are holding has disconnected from the pile. A group member should measure the length between your hands when the disconnection occurred, (in centimeters) and record it as “separation length at break” in table 2.

7. Repeat steps 4-6 for a total of three trials.

8. Repeat steps 4-7 with the shortened length spaghetti noodles, recording values in Table 3.

**Observations**

**Table 1. Spaghetti Flow Properties**

<table>
<thead>
<tr>
<th>Spaghetti type</th>
<th>Flow observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Spaghetti Strength Properties—Normal Spaghetti**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Initial separation length (cm)</th>
<th>Separation length at break (cm)</th>
<th>Difference in length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table 3. Spaghetti Strength Properties—Shortened Spaghetti

<table>
<thead>
<tr>
<th>Trial</th>
<th>Initial separation length (cm)</th>
<th>Separation length at break (cm)</th>
<th>Difference in length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>Average</td>
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Calculations
Calculate the average difference in length for each type of spaghetti you explored, record the value for each type in table 2 or table 3, as labeled.

Analysis
1. The names of many polymers begin with the prefix *poly*. List the names of any polymers that you know.
2. Look around you. Do you see any plastic materials? List at least five objects made of plastic.
3. When plastics are recycled, it is important to separate different types of plastics from one another. To aid in this separation, common plastics are assigned a code number to identify the type of plastic. The code is a recycle triangle with a number inside. Identify and list at least three items with different recycle codes and indicate the type of plastic used. (You will have to look up the type of plastic for each code number online.)
4. Gasoline, paraffin, and polyethylene (the plastic used in milk bottles) all have essentially the same molecular composition, yet their physical properties are quite different. Based on the spaghetti model, describe how these three substances might differ on a molecular scale.
5. Why were different lengths of spaghetti noodles used in this activity?

Conclusion
Write a one- to two-sentence summary describing how the properties of polymers depend on their molecular structure.