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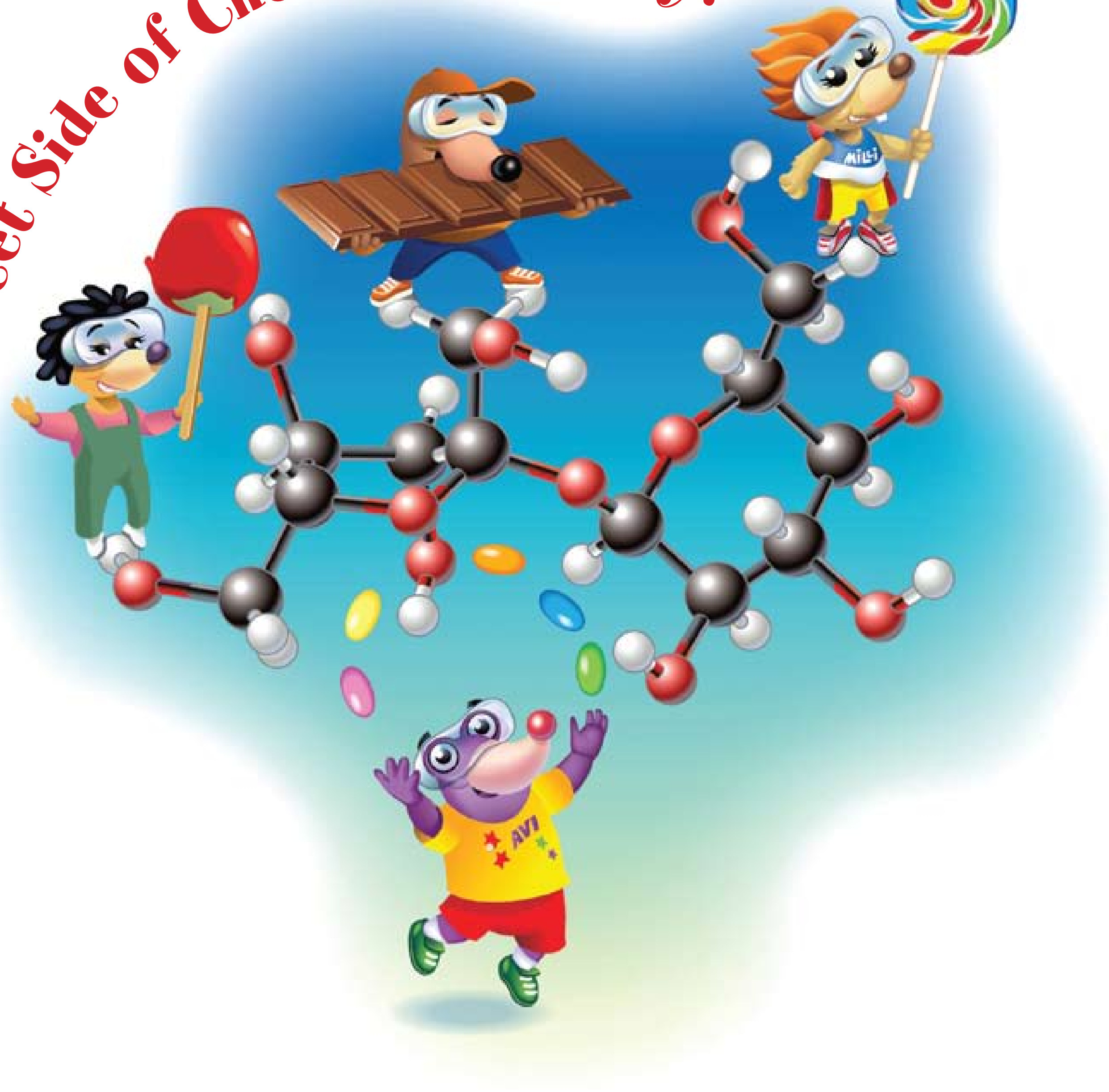
The Sweet Side of Chemistry: Candy!



Candy: Feel Good Chemistry!

By Ronald P. D'Amelia and Marilyn D. Duerst

Candy… How sweet it is!!! Don't you love the sweet taste of jelly beans, gummies, jellies, caramels, toffee, fudge, and gum drops? Or how about lollipops, taffy, cotton candy, candy canes, hard candy, candy bars, chewing gum, and licorice? Candies come in many different textures, from soft and chewy to hard and brittle. The texture of a piece of candy depends mainly on the number, size, and type of the sugar crystals, the amount of sugar compared to water, and the other ingredients present.

Did you know that most types of candy are made of sugar from two kinds of plants: sugar cane and beets? The common form of sugar is called sucrose ($C_{12}H_{22}O_{11}$), a molecule made up from glucose and fructose (see front cover). But what else is in the recipes for candy? Many contain corn syrup, milk, gelatin, chocolate, and vegetable oils, for starters, along with other ingredients such as flavors and food colorings. Sour candies, for example, contain citric acid ($C_6H_8O_7$), the acid that makes grapefruit sour. All these ingredients are combined to make a sweet and flavorful product.

In this edition of *Celebrating Chemistry*, you will learn about the chemistry in candy making, certain properties of candy, and much more. Read on to learn more about chemistry's sweet side. Additional articles are available online on the Educational Resources page at www.acs.org/ncw.

Ronald P. D'Amelia, Ph.D. retired from Kraft/Nabisco as a senior Principal Scientist after 32 years of service. He is currently an Adjunct Professor of Chemistry at Hofstra University, the Faculty Advisor to the Hofstra chapter of student members of ACS, and a Fellow of the ACS.

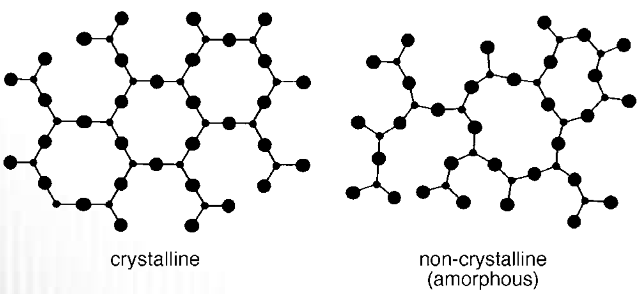
Marilyn Duerst is a Distinguished Lecturer in Chemistry at the University of Wisconsin-River Falls, who enjoys collecting samples of elements, sand, and minerals.

Hard Candy - A Glass Act

By Ronald P. D'Amelia and Robert A. Yokley

Hey, put that candy down, you're eating *glass*!!

Did you know that hard candy is technically a glass? Believe it or not, hard candy and glass are alike in many ways. They are generally solid, easily shaped before cooling, fragile, easily broken and clear to translucent in visible light. They are also **amorphous**, which means their molecules are not arranged in an orderly fashion like something that is crystalline. Because hard candy glass is so much like real glass, it is sometimes used in movies to create the "bottle" that gets broken over someone's head in a fight scene!



However, there are two main differences between glass made from hard candy and real glass. One is that hard candy glass is made mostly of table sugar (sucrose), and real glass is made mostly from sand (silicon dioxide, or SiO_2). The other difference is the temperature needed to make glass from hard candy (302 °F, or 150 °C) is much cooler than what is needed for making sand glass (3092 °F, 1700 °C). A special thing about both kinds of glass is that they do not melt like many crystalline solids. Crystalline solids have sharp melting points. Instead, amorphous solids soften or flow at a temperature called the **glass transition temperature**. This temperature for candy glass is around 140 °F (60 °C), while for sand glass, it's around 970 °F (520 °C).

Sucrose, made from either sugarcane or sugar beets, is the main ingredient for making candy. It is composed of two simple sugars called glucose (the main ingredient in corn syrup) and fructose (the sweetest of all sugars). A common recipe for making hard candy includes a mix of 3½ cups sugar, 1 cup corn syrup, 2 cups water, plus flavor and coloring. As this mixture is heated, more and more of the sucrose and corn syrup dissolve. The syrup gets thicker and stickier (more viscous) as the water molecules escape in the form of steam (water vapor). As the temperature finally reaches 302 °F, the hard candy mixture contains only 2 or 3% water. The amount of sucrose in the mixture and its final temperature give the candy its special physical properties. Cooking the mixture to different temperatures produces different kinds of candy. For example, cooking the mixture to 240 °F will produce a fudge-like consistency while cooking to 264 °F produces toffee.

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Robert A. Yokley, Ph.D. recently retired from Syngenta, where he managed a mass spectrometry and method development group. He enjoys traveling, playing tennis and exploring new places with his wife Phyllis in his vintage Triumph sports car.

Sour Candy Surprise

By Marilyn Duerst

Introduction: Many people like chocolate candy … but what about other kinds of candy? Some are both sweet and sour, while some are just plain sour, and make your mouth pucker! Instead of eating them, let's find out what happens when sour-tasting candy is mixed with some white powders found in your kitchen. Sour taste is the body's way of identifying acids, so if your candy tastes sour, it contains an acid. To test for an acid, try this!

Materials:

- **4 pieces of your favorite sour candy (example: Lemonhead, Warheads, SweetTARTS, Pixy Stix, sour gummy candy, etc.)**
- **1 peppermint (or other non-sour candies)**
- **4 small plastic bowls or cups**
- **Plastic spoons**
- **Lemon juice**
- **Paper towels for clean-up**
- **Baking soda**
- **Sugar**
- **Salt**

Procedure:

Part 1

Let's find out what happens when lemon juice, an acid, is mixed with some white powders found in your kitchen.

1. Line up 3 small bowls or cups.
2. Add about 1 teaspoon table salt into the first one, 1 teaspoon of sugar into the second one, and 1 teaspoon of baking soda into the last one.
3. Add about 1/4 cup of water to each bowl and stir.
4. Add five drops of lemon juice to each bowl and see what happens. Record your observations in the table below. Which solution reacted with the lemon juice? How? All acids will react in a similar way–so now you know a test for acids.
5. Carefully wash out the bowls and dry them with paper towels.

	Salt *Sodium chloride (NaCl)*	**Table sugar** *Sucrose ($C_{12}H_{22}O_{11}$)*	**Baking soda** *Sodium bicarbonate ($NaHCO_3$)*
Lemon Juice			

Marilyn Duerst is a Distinguished Lecturer in Chemistry at the University of Wisconsin-River Falls, who enjoys collecting samples of elements, sand, and minerals.

Milli's Safety Tips Safety First!

ALWAYS:

- Work with an adult.
- Read and follow all directions for the activity.
- Read all warning labels on all materials being used.
- Use all materials carefully, following the directions given.
- Follow safety warnings or precautions, such as wearing gloves or tying back long hair.
- Be sure to clean up and dispose of materials properly when you are finished with an activity.
- Wash your hands well after every activity.

NEVER eat or drink while conducting an experiment, and be careful to keep all of the materials away from your mouth, nose, and eyes!

NEVER experiment on your own!

Part 2

Now, let's find out what happens when you mix candy with a baking soda solution.

1. Line up one small bowl or cup for each type of candy you have.
2. Add about one teaspoon of baking soda to each bowl or cup.
3. Add about 1/4 cup of water to each bowl and stir.
4. Drop one kind of candy into each bowl. Which candies do you think contain acid? How do the candies that reacted taste?
5. Carefully dispose of the bowls.

	Baking soda *Sodium bicarbonate*
Trial 1 Peppermint or non-sour candy	
Trial 2 ____________ (name of candy)	
Trial 3 ____________ (name of candy)	
Trial 4 ____________ (name of candy)	

Where's the chemistry?

Sour candies contain acids, usually citric acid, that are found in sour fruits such as grapefruits and lemons. These acids react with certain substances like baking soda to form bubbles of **carbon dioxide** (CO_2). When you bake cookies, muffins, cakes or pancakes, the recipes usually contain baking powder, which contains both a powdered acid and baking soda, allowing carbon dioxide bubbles to begin to form even without the presence of any other acid.

CANDY CHEM MUNITY

Peppermint oil comes from a plant, and candies flavored with it help some people concentrate better.

Lollipops have a glassy form of sugar that is NOT small, white crystals.

Sour candy contains citric acid, the molecule that makes grapefruits and other citrus fruits sour.

Chocolate-covered cherries and mints start out with hard centers. The chemical called **invertase** helps to soften their centers to the consistency we love.

Cotton candy, found at carnivals and amusement parks, is almost pure sugar that has been melted and then spun.

Lollipops are hard candies with sticks placed into them before they harden.


Gummies contain flavor, sugar, and **carrageenan** (made from seaweed), which makes them chewy.
Enough jelly beans are eaten in a year to circle the earth more than five times.
Licorice contains a smelly compound found in a spice called anise.
Chewing gum is made to be chewed but not swallowed, unlike most other candies.
Rock candy is almost pure **crystalline sucrose**, and has large sugar crystals.
Marshmallows are made by whipping air into a mixture of sugar, corn syrup, **gelatin** (made from animals), egg whites, and flavoring.

Chew On This!

The Chemistry of Chewing Gum: A Sticky Situation

Ronald P. D'Amelia

Chewing gum dates back to the ancient Greeks, who chewed bark from the mastic tree. The ancient Mayans used another material to chew as an edible treat. It was a gummy latex (sap) from the sapodilla tree called *chicle*. Today chewing gum is a lot sweeter and tastier … and a lot easier to find!

Chewing gum is a special product, and unlike any other food. It is one of the oldest types of candy, and the only one that is designed to be chewed, not swallowed. It also delivers sweetness and a flavor sensation that lasts over time.

Today, sugar chewing gum is made with five main kinds of ingredients: chewing gum base, sweeteners (sugar-sucrose), corn syrup, softeners, and flavors. There are two kinds of chewing gums, sugar and sugar-free. Chewing gum comes in four choices: stick (or tab), bubble, ball, and coated. In sugar-free gums, chemicals called **sorbitol** and **mannitol** and an intense sweetener like **aspartame** (Nutrasweet) or **sucralose** (Equal) replace the sugar and corn syrup.

A **gum base** puts the "chew" in all chewing gums, by providing a smooth, soft texture. The base holds (or binds) together all the other ingredients. This gum base is usually made of a blend of edible polymers such as **elastomers** (rubber) and **resins** (polyvinyl acetate). It also includes other ingredients, such as waxes and softeners to give it a good texture, and other ingredients for sweetness and flavor. Only safe and approved ingredients are used in the making of chewing gum. There are many steps involved in making a single piece of gum. A description of how chewing gum is made can be seen at www.gumassociation.org.

Chewing gum can also have health benefits such as stimulating saliva, helping to clean the teeth, easing tension, and freshening breath. Sugar-free chewing gum can also reduce symptoms related to heartburn and help fight tooth decay. But chewing can also cause some dental problems if you do it too much … and can make a mess if it's not disposed of properly.

Most gum makers market their product as candy, but others have stretched its use. Today, chewing gum helps to deliver vitamins and caffeine. It also helps those who are trying to break the smoking habit. One of the oldest candies is not just for fun anymore!

Try this…

Let's calculate and compare the amounts of sugar, sugar alcohols, and gum base in sugar and sugar-free chewing gum. You will need a package of stick chewing gum, a package of sugar-free stick chewing gum, and a calculator!

Procedure

1. Look at the "Nutrition Facts" for each gum and find the weight of a single piece of gum.
   Weight of one stick of sugar gum: ________ grams
   Weight of one stick of sugar-free gum: ________ grams
2. Next find the weight of sugar and sugar alcohols in a single piece of gum. These materials are shown under "Total Carbohydrates."
   Weight of sugar in sugar gum: ________ grams
   Weight of sugar alcohols in sugar-free gum: ________ grams
3. Next calculate the percentage (%) of sugar or sugar alcohols by dividing their weight (what you wrote in answer 2) by the total weight of the stick (what you wrote in answer 1), and then multiply your answer by 100%.
   % of sugar in a stick of sugar gum: ________
   % of sugar alcohols in a stick of sugar-free gum: ________
4. Finally, to find the % gum base, subtract the % of sugar (or the % of sugar alcohol) from 100%. The remainder is the % gum base.

Floating Letters!

By Marilyn Duerst

Introduction:

Have you ever wondered how the letters on small, round, colored candies got there? Are they safe to eat? Instead of eating those candies, let's try some experiments with them! Find an adult to help you with the warm water and clean-up. Be careful!

Materials:

- **Bag of M&M's and/or Skittles**
- **Several small plastic bowls**
- **Very warm water**
- **Stir sticks or plastic spoons for stirring**

Procedure:

1. Put about 1 cup of very warm water into each of three small bowls.
2. Add 3 red M&M's to one bowl, 3 blue M&M's to another and 3 yellow ones to a third. You can also choose any other colors of Skittles or M&M's, except for brown.
3. After about a minute, what has happened to the 'm' or 's' letters? What other observations can you make about the water in each bowl?
4. Using a spoon, take a spoonful of water from one bowl and put it into a clean bowl. Add in a spoonful of water from one of the other bowls and stir. What do you observe about the water?
5. Using a spoon, make other mixtures and record the results.

SAFETY SUGGESTIONS:

All of Milli's Safety Tips – Safety First

Where's the chemistry?

The letters on the M&M or Skittles candy do not dissolve in water and are adhered to the candy with an edible glue that dissolves in warm water. Since the letters are less dense than water, the letters peel off and float as the rest of the candy shell dissolves.

The colored dyes of the candies will color the water. Objects that are red absorb most of the colors of visible light EXCEPT red, which is reflected to our eyes. Objects that are blue absorb most of the red and yellow colors of light, and reflect blue light to our eyes. If you mix the two, only violet light is reflected to our eyes and the water looks purple.

Yellow objects absorb violet light, and blue objects absorb red and orange light, so the mixture of yellow water and blue water looks green, the only color in the visible light spectrum that bounces back to our eyes.

SUGAR vs. Sugarless (Sugar-Free) Candies

By Analice Sowell

There are many wonderful and delicious types of treats made by candymakers. In fact, if you can think of a certain kind of chocolate candy or fruit-flavored candy, chances are that somebody, somewhere, probably makes it!

But what about candy for people who can't eat sugar? For example, diabetics (people who have the illness called diabetes) cannot safely digest sugar. Eating traditional candy made with granulated white sugar (sucrose) could be bad for diabetics … so, how do we help them satisfy their "sweet tooth?"

Candy companies have created "sugar-free" or "sugarless" choices for customers. These candies contain chemicals that are known as sugar substitutes. These chemicals provide a sweet taste like sucrose, but without the health problems that sucrose can cause for diabetics.

If you look on the label of sugar-free candy, you might see the words maltitol, xylitol, sorbitol, or mannitol. These sugar substitutes are known as sugar alcohols, and they make sugar-free candy taste sweet like regular candy. However, these substitutes are not completely absorbed by the body. This makes them a better choice for diabetics, because they do not affect the sugar levels in the blood as much as sucrose does. Diabetics still have to be careful, though, because sugar-free doesn't mean fat-free!

Other people may like sugarless candies because they are concerned about their weight, or they want to keep their teeth nice and healthy. However, eating too much sugarless candies can also be bad, because it could give you an upset stomach!

Analice Sowell is a member of the ACS Committee on Community Activities and the Memphis Local Section. She currently teaches high school honors chemistry and a special topics course in materials science at Memphis University School in Memphis, TN.

The Adventures of Meg A. Mole, Future Chemist

Dr. Rich Hartel, Professor of Food Engineering

I went to Madison, Wisconsin to meet Dr. Rich Hartel. He's a professor of Food Engineering at the University of Wisconsin-Madison. Along with his student researchers, he studies the science of ice cream, chocolate, and candy. "As food scientists, we are always looking for ways to make these foods even better."

What does Dr. Hartel enjoy about his job? "First, I am learning something new all the time, from our own research, and what other researchers are doing. Second, as a teacher, I get to learn from my students. It's a great combination."

In the university, they work a lot in the lab, carefully running experiments to learn about the science behind foods. Dr. Hartel explained that, "We learn about what happens when we actually make foods. In our ice cream pilot plant, for example, we have nearly a dozen ice cream makers, and each puts its own spin on the ice cream it produces."

Growing up, Dr. Hartel was interested in science, and his teachers encouraged him. But his parents didn't always appreciate him "taking things apart to see how they worked!" He also knew he needed "many other skills to be successful as a scientist, such as writing and history."

Dr. Hartel wanted me to remember how important this work is. He explained, "Next time you are playing with your food, remember that you're studying Food Science." Next stop for Meg? I'm going to the ice cream shop to do my own research!

The Adventures of Meg A. Mole, Future Chemist

Sally Mitchell, Chemistry Teacher

Candy Chemistry … Can it get any better? To celebrate National Chemistry Week, I decided it was time to go to high school! I met Sally Mitchell, a teacher at East Syracuse Minoa High School in New York. Ms. Mitchell teaches Food Science, which she explained was "the study of the physical, chemical, and biological properties of foods." In Food Science, you learn about all of the chemical reactions that take place when you cook!

Ms. Mitchell told me that her students' favorite topic is candy chemistry. In class, they get to "make different kinds of candy such as fudge and peanut brittle." I wonder if moles are allowed to go to high school in New York?

In the school's laboratory, students "wear goggles and lab aprons, and use special gloves to handle hot dishware." And since they are working with foods, they have to tie back long hair and "wear hair nets and gloves when handling food."

Growing up, Ms. Mitchell was always interested in science and experimenting in the kitchen. When she was ten years old, she began experimenting with making chocolate chip cookies and fudge. Fudge was especially tricky, she said. "It took over 20 years of trial and error," she told me, "and now I have figured out the perfect peanut butter fudge recipe!"

Ms. Mitchell also said "the best thing about being a scientist is that you get to experiment and make mistakes … but then you get to go back into the lab and try something else until it works." Every child has the chance to learn more about the chemistry of Food Science – just look in your very own kitchen!

Word Search

Try to find the words listed below — they can be horizontal, vertical, or diagonal, and read forward or backward!

O I N H L T Y N I O C E G Y Y B O O C

A T R S E O S O A S V I E L O R T A P

L E S E I N A I A S S I X U U X R Y P

O A M S M R S T S E U E S O T C U R F

T C M A O Y E U I C S C H C L T O A C

I L C E N I L L A T S Y R C O R C S S

B A M O R P H O U S R E M O T S A L E

R T P R E R S S P R I T E R S O I A R

O E O P H Y S I C A L P R O P E R T Y

S X E L E C A R B O H Y D R A T E Y Y

AMORPHOUS	GLUCOSE	SOLUTION
CARBOHYDRATE	LATEX	SORBITOL
CRYSTALLINE	PHYSICAL PROPERTY	SUCROSE
ELASTOMERS	POLYMER	VISCOSITY
FRUCTOSE		

Celebrating Chemistry

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What is the American Chemical Society?

The American Chemical Society (ACS) is the largest scientific organization in the world. ACS members are mostly chemists, chemical engineers, and other professionals who work in chemistry or chemistry-related jobs. The ACS has more than 161,000 members. ACS members live in the United States and different countries around the world. Members of the ACS share ideas with each other and learn about important discoveries in chemistry during scientific meetings held around the United States several times a year, through the use of the ACS website, and through the many peer-reviewed scientific journals the ACS publishes. The members of the ACS carry out many programs that help the public learn about chemistry. One of these programs is Chemists Celebrate Earth Day, held annually on April 22. Another of these programs is National Chemistry Week, held annually the fourth week of October. ACS members celebrate by holding events in schools, shopping malls, science museums, libraries, and even train stations! Activities at these events include carrying out chemistry investigations and participating in contests and games. If you'd like more information about these programs, please contact us at **outreach@acs.org**.

ACS Chemistry for Life®

Words to Know

Amorphous: A solid that is made up of particles that aren't arranged in a specific pattern. Examples include clay, glass, plastic, and rubber.

Carbohydrate: A group of chemical compounds including sugars, starches, and cellulose (wood fiber) containing the elements carbon, hydrogen, and oxygen.

Crystalline: A solid that is made up of atoms arranged in a highly-ordered, three-dimensional structure. Salt and diamonds are examples of crystalline substances.

Elastomer: A substance that can be stretched, but will then return to its original shape when released, like a rubber band.

Fructose: Another name for fruit sugar. Fructose is a simple sugar found in berries, fruit juices, and honey. It is the sweetest of the common sweeteners.

Glucose: Also called grape sugar or blood sugar, this is a simple sugar that can travel through your body in your bloodstream.

Latex: A milky viscous sap from certain trees and plants. It is used to make many things we use, including synthetic rubber gloves and some types of paint. Some people are allergic to latex.

Physical Property: A characteristic of a substance that can be measured and observed without changing the chemical make-up of the substance. Examples are a substance's color and density.

Polymer: A giant molecule consisting of simple, repeating units that are hooked together to form a very long chain. *Poly* means many, and *mer* means part.

Solution: An evenly blended mixture that can exist in many forms. Sugar water, air, and sterling silver are all examples of solutions.

Sorbitol: A sweet-tasting crystalline sugar-substitute alcohol compound, with a formula of $C_6H_8(OH)_6$. It is sometimes used to make sugar-free candy and gum.

Sucrose: The sugar found in your sugar bowl. Sucrose is a crystalline carbohydrate that comes from sugar cane and sugar beets. It is a molecule made up of two simple sugars, glucose and fructose, and has a formula of $C_{12}H_{22}O_{11}$.

Viscosity: A measure of a liquid's resistance to flow. Honey is very viscous, and water is not.

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