There is more to delicious food than taste; it also must have the right texture. The *elasticity* is one of the ways to characterize the texture of food in scientific terms.

## Measuring Elasticity

The *elastic modulus* can be measured by exerting a force on a food, and measuring the distortion. If $F$ is the applied force, $A$ is the area over which the force is applied, $\Delta L$ is the distortion and $L$ is the initial thickness of the food, then we have

$$F = EA\frac{\Delta L}{L} \quad \Rightarrow \quad E = \frac{F/A}{\Delta L/L}$$

Thus by measuring $\Delta L$ for a known $F$ we can deduce $E$.

Having a way to quantify elasticity is extremely useful for understanding recipes, because it gives understanding of why different foods with completely different ingredients can have similar textures. We will see examples of this today, both when we compare different pancake recipes, and in this week's lab when you examine the fundamental basis of Heston Blumenthal's famous hot and cold tea recipe.

## Microscopic Origin of Elasticity

What determines $E$? Why are some foods soft and others hard? The elastic modulus is determined by two factors: (i) the energy $U$ of the bonds in the food; and (ii) the density of the bonds, or the distance $\ell$ between them. The fundamental equation is

$$E = \frac{U}{\ell^3}.$$

This equation states that a stiffer material with higher $E$ either has a higher bond energy $U$, or a smaller $\ell$, or both.

The edX lectures focus on steak, where an old cooking method – the so-called thumb test – says that steak gets stiffer as it cooks. $E$ increases *both* because $U$ increases, and $\ell$ decreases. $U$ increases because additional bonds form in the steak during cooking. The length $\ell$ decreases because there is water loss during cooking, and this makes the distance between bonds shorter.

## Candy Making

We also discuss, in the context of Bill Yosses candy apple, the basic science of candy making. Here, elasticity has long been a proxy for measuring the temperature of sugar water mixtures – the different regimes are called hard ball; soft ball; etc. These fundamentally measure the elasticity of the material. Here $E$ is mainly set by $\ell$ which increases when the water fraction increases. Water content is carefully controlled in candy making due to the dependence of the boiling point of sugar water mixtures on the mass fraction of dissolved sugar.

## Addditional materials available online

- Molecular theory of interactions and resulting elasticity (Advanced)
- ATK video on how to make a steak.

## Science Review Questions

1. Suppose you are given a sugar crystal, which is a cube with each side 10 cm. You place a 1 kg weight on the cube, and measure that the cube compresses by a distance 2.5 nm. What is the elastic modulus of the sugar crystal?

2. Your friend is a chemist and tells you that the bond energy between the molecules in a sucrose crystal come from multiple hydrogen bonds and van der Waals interactions. The energy is $U = 2.7 \times 10^{-17}$ J. Using your measurement of the elastic modulus, find $\ell$, the distance between the molecules.

3. Look at the Wikipedia page for sucrose to find out the distance between the molecules in a sucrose crystal. How did you do?

4. Which of the following are the names given to sugar water heated to different temperatures:
   (a) Firm Crack
   (b) Firm Ball
   (c) Hard Crack
   (d) Soft Ball
   (e) Squishy Ball

5. Which of the following elements were not part of Bill Yosses spectacular dessert:
   (a) Angel Food Cake
   (b) Sorbet
   (c) Chocolate
   (d) A Tuille

6. True or False. Bill Yosses advocates making angel food cake for State dinners in a microwave.