1. Calorimetry is:
   a. A way to measure how much energy is in something.
   b. A way to determine the temperature of something.
   c. The measure of nutrients in a food.
   d. A technique that is no longer in use.

2. Which of the following statements about Calories is true?
   a. Some Calories are good, some are bad, depending on the food they come from.
   b. If you don’t exercise, you aren’t using Calories.
   c. We get Calories from food through the energy stored in molecular bonds.
   d. Cold food has fewer Calories than hot food.

We have previously been discussing the characteristics of food, food additives and food safety. In this lesson we will consider the nutritional components of food that were briefly mentioned in Lesson 1.1. In the next two lessons we will learn about the major macronutrients and micronutrients that are in our food, and explore the relationship between macronutrients and calories.

We have all heard of a CALORIE, but what is it?

You are probably familiar with the idea that eating food provides us with the energy we need to live. Indeed, the amount of energy in any given food can be found on its label, listed as the number of Calories. But what does this unit of energy mean to us? To address this question let’s look at how we measure the Calories in food. Energy can exist in many forms: heat is one form of energy that you can feel, and the bonds that hold molecules together contain energy that can be released as heat when the bonds are broken. As we will see, all the energy we get from food comes from breaking carbon-carbon bonds in macronutrients to release energy. Calorimetry is a laboratory technique that is used to calculate how much energy is in a given substance by burning it and measuring the heat released, and the amount of energy is described in units of Calories. We tend to think of Calories in regards to food, but it can also refer to the other types of energy. In technical terms, calorimetry is the study of the amount of energy that is exchanged between a substance
LESSON READINGS

and its surroundings before and after a chemical or physical reaction, as measured by changes in heat. When we think about Calories in food we are referring to the energy in the molecular bonds of the macro-nutrients, as you will see throughout this lesson.

History and use of the calorimeter

In the late 1700s a French scientist named Antoine Lavoisier developed the first known calorimeter, which he used in a series of studies that led him to conclude that animals produce energy through combustion. Lavoisier’s work laid the foundation for future studies in metabolism, leading many people to call him “the father of nutrition”. Since Lavoisier’s early experiments, several types of calorimeters have been developed, all using the same premise of measuring the amount of heat given off by combustion.

A combustible reaction is when something with carbon reacts with oxygen (by burning it), yielding carbon dioxide. This reaction is the underlying foundation of metabolism, when the carbon-carbon bonds in glucose are broken/ metabolized to release energy:

\[
\text{C}_6\text{H}_{12}\text{O}_6 \text{ (glucose)} + \text{O}_2 \text{ (oxygen)} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy (heat)}
\]

We breathe in the oxygen, which is used to metabolize our food. When glucose is broken down the bonds are broken, and this is where the energy in our food comes from. The CO₂ and H₂O that is created during metabolism is released from our bodies through sweat and our breath. In fact, we exhale approximately 182 grams of carbon each day, which is about the amount found in 2,200 Calories of food!

Calories are a unit of energy that we think of in terms of heat, but how does measuring Calories in a calorimeter relate to the way food is metabolized in our bodies? In the late 1800s a scientist named Wilber O. Atwater developed a respiration calorimeter: a small room just large enough for a person to step into, which measured the changes in oxygen, carbon dioxide and heat. Atwater used the idea that combustible reactions are occurring in our bodies all of the time, and that by measuring the oxygen, carbon dioxide and heat coming from a person he could calculate the amount of energy being used by the body. Upon making these measurements after a person in the respiration calorimeter consumed a variety of foods, Atwater determined the number of Calories in carbohydrates, proteins and fats, values that are still used today.

3. Combustible energy is NOT:
   a. How we get energy from our food.
   b. The type of energy needed to make ice melt.
   c. The energy given off when something reacts with oxygen.
   d. The energy given off when something is burnt.

DEFINITIONS OF TERMS

Combustion — The process of burning something.

For a complete list of defined terms, see the Glossary.

Workbook
Lesson 1.4
DEFINITIONS OF TERMS

Basal metabolic rate (BMR) — The rate that the body uses energy while at rest to keep vital functions going, such as breathing and keeping warm.

For a complete list of defined terms, see the Glossary.

Is counting Calories helpful?

Now that we have a better idea of what a Calorie is, how do you know how many Calories to eat? Every person needs a different amount of calories, depending on their activity level, gender, age, weight and height. For example, days that you exercise you may need to eat more food to maintain your energy level compared to days when you are sitting in class for hours at a time. Let’s say we have two identical people, but one runs 3 miles, while the other plays video games. The one that runs will need to eat about 300 more Calories to “pay” for the exercise. In addition to the energy you use when you exercise, the number of Calories that you need is the amount of Calories you use to maintain bodily functions; this is called the basal metabolic rate (BMR). Each person will have a unique BMR, that will depend largely upon how much energy is required to maintain your body mass. For example individuals with more muscle mass will have a higher BMR than people that have more fat mass. In general, the more muscle a person has, the higher their BMR will be. Knowing how many Calories you need to maintain a healthy weight will help you decide what foods are better choices for you.

Explosive science: Bomb Calorimetry

As you can imagine, using the complicated respiration calorimeter to measure Calories in all types of foods is not feasible. A common way to measure Calories is the bomb calorimeter. In this technique, the food of interest is weighed and placed in a container that is submerged in water. The food is lit on fire, causing a combustion reaction with the food. The burning food will heat up the surrounding air, which will escape through a copper tube or coil. This air will then heat up the water, and the change in temperature of the water is used to calculate the Calorie content of the food. The food will be weighed again after the reaction so that the Calories per gram of food can be determined. This is how the Calorie information on the back of your food packages is determined.

Figure 3: A bomb calorimeter is used to measure the heat of a reaction. Through lighting food on fire, the amount of Calories in that food can be calculated.

Figure 4: In 2010 Dr. Mark Haub made headlines for losing 27 lbs. by eating only processed foods like Twinkies. The trick? He cut his Caloric intake in half, adding evidence to the belief that it isn’t the nutritional value of food that you eat that leads to weight gain or weight loss, it’s the amount of total Calories.
LESSON READINGS

Are all calories created equal?

Let’s say you perform bomb caloriometry on a candy bar and an apple and peanut butter and find that the number of Calories in each is identical. Are the Calories equal? Foods that have a lot of added sugars and unrefined carbohydrates are sometimes said to have ‘empty calories’. For example, the candy bar is full of empty calories, but the apple with peanut butter has Calories plus other nutritional value, like vitamins, minerals and fiber. So, what the term empty calorie hints at is the amount of micronutrients per Calorie in the food; a food with a lot of Calories, but without the beneficial vitamins and minerals has a lot of empty Calories. In this way, the Calories from the fruit seem to be ‘better’ than the Calories from the candy bar. But be careful, the term ‘empty calories’ is a bit of a misnomer, because the food is not empty of calories, but is instead empty of beneficial nutrients. People that eat a diet full of empty Calories, like Dr. Haub in the photo above, must rely on a nutrition supplement to supply them with their other nutritional needs. So, all calories are equal but two foods supplying the same number of calories may be unequal.

The USDA has recommended daily intakes for empty calories based on gender, age and physical activity to ensure that we all eat enough of the important micronutrients without overeating Calories. For example, if you are supposed to eat 2000 Calories in a day, and you eat 300 empty Calories then you need to get all your micronutrients in the reaming 1700 Calories that day. For a teenaged male exercising 30 minutes a day, it is recommended that he consume no more than 265 empty calories a day. A female of the same age and physical activity level should consume no more than 160 empty calories a day. This is about the amount of Calories in one candy bar or soda.

Caloric density

In terms of choosing food to maintain a healthy weight, or for weight loss or weight gain, it is the number of Calories eaten that will make the most difference. Caloric density is defined as the amount of energy provided per a measured volume of food. It can also be thought of as the absence of components in food that do not give you energy: water and non-digestible substances like fiber. For example, something that is high in fat will be more calorically dense than something high in protein or carbohydrates, because lipids have more calories per gram (9 Calories per gram) than protein (4 Calories per gram) or carbohydrates (4 Calories per gram).

Figure 5: High fiber foods like vegetables will fill your stomach for little calories, unlike calori- cally dense fats like oil, or fiber free proteins like chicken.
A tablespoon of oil will have more calories than a tablespoon of sugar, so the oil is more calorically dense than sugar. Additionally, processed foods are likely to be more calorically dense than whole foods, because the act of processing food breaks down and removes fiber. We can also think of caloric density in the reverse: what volume of a food do you need before you reach a certain number of Calories? In Figure 5 you can see that 400 Calories of oil does not take up as much volume as 400 Calories of chicken or vegetables.

Serving sizes and the calorie surprise!

The more often you pay attention to the number of Calories in foods, the more likely you are to be surprised by where Calories can hide. Using the pictures below, take a moment to rank the foods from the lowest to highest number of Calories:
Which food do you think contains the most Calories? In the pictures on the previous page, the salad dressing has the fewest Calories, with only 150. A serving of salad dressing however is only 2 tablespoons, about the size of a golf ball, and we tend to pour on more than one serving. A small serving of french fries at a popular fast food restaurant will add around 250 Calories to your meal. Beverages are a top source of unexpected Calories because they don’t have any fiber and are usually laden with sugars to make them sweeter. For example, a 16 oz. bottle of soda contains around 190 Calories, and a medium flavored espresso drink with whole milk from a popular coffee shop can contain 400 – 500 Calories! A ham and cheese sandwich with lettuce and tomato on wheat bread only contains around 350 Calories. A burrito from a fast food chain with steak, rice, beans and cheese has nearly 1000 Calories! Did any of these surprise you?

The absorption dilemma!

As previously mentioned, the Calories that are listed on a Nutrition Facts panel of foods were measured using a bomb calorimeter. However, two foods containing the same number of Calories may be digested and absorbed differently in our bodies. For example, if you measure the number of Calories in raw vegetables and cooked vegetables, the calorimeter will tell you that the number of Calories has not changed significantly. Your body, on the other hand, cannot absorb all of the proteins and carbohydrates in uncooked vegetables because they are still tangled up in the fibers of the vegetable. This brings up the idea of **digestible energy**, which is the amount of energy from food that you actually absorb. So the number of Calories listed on foods tells us the maximum amount of energy we could absorb from the food, unfortunately there is no easy way to measure digestible energy. In general, energy is readily absorbable from foods composed of empty calories, while whole foods that are likely to have less digestible energy than total Calories.

The amount of digestible energy that is absorbed may also vary from person to person, and can depend on your health, age, ethnicity, and microbiome. Your **microbiome** is the world of microorganisms, mostly bacteria, which have adapted to living in your intestines. These bacteria feed off of the indigestible part of your diet, like fiber. They will help to break down these fibers into smaller particles that you can more readily absorb, similar to the way cooking can release nutrients. The types of bacteria that live in your gut are unique to you, much like a fingerprint. Some research suggests that people who are obese have a very different microbiome compared to people that are thin. This might mean that the microbiome of an obese individual is better at breaking down foods, so that person can absorb more digestible energy.

**Digestible energy** — The energy that is available by digestion. This can be measured as the difference between the amount of energy eaten and the amount of energy excreted in the feces.

**Microbiome** — The community of microorganisms that live in or on our bodies.

For a complete list of defined terms, see the **Glossary**.

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**Figure 6**: *Enterococcus faecalis* is a kind of commensal bacteria that lives in the gut.
If you drank 150 Calories from a soda, or ate 150 Calories in a sandwich, which one will you absorb more energy from? Why?
### TERMS

<table>
<thead>
<tr>
<th>TERM</th>
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