BOX 1.2
ETYMOLOGY

Why is it good to be "the big cheese," but bad to be "cheesy"? Where does the word *cheese* come from? For these answers, we turn to etymology, the study of formation and development of words. *Cheese* derives from the Latin *cāseus*, passing through such forms as *chasī* (Old High German), *kasī* (Old Saxon), and *cēse* (Old English). Some other European languages have similar words for cheese: kaas (Dutch), käse (German), cáis (Irish), queso (Spanish), and queijo (Portuguese). *Casein* also comes from this word.

The Latin *jūs*, juice, evidently referring to the whey, led to northern European words for cheese: juusto (Finnish), juust (Estonian), and ost (Norwegian, Swedish, Danish, Icelandic).

A third Latin word, *formaticum*, means "shape" and was used in the term *formaticus caseus*, "shaped cheese." This gave us two other words for cheese: fromage (French) and formaggio (Italian).

The Greek word for cheese is *τυρί*, pronounced tyri. It is the source of the word *tyrosine*, an essential amino acid that was discovered in casein in 1846. It is also the root of *turophile*, "cheese lover."

Our English word *sour* comes from the Indo-European word *syr* or *sir*, relating to the souring of cheesemilk. The word is used for cheese in Slavic languages: сыр ("syr," Russian and Belarusian), сир ("seer," Ukrainian, Serbian, Croatian), сирене ("seerenneh," Bulgarian), ser (Polish), sýr (Czech), and syr (Slovak). Baltic languages also use syr/sir as the root: siers (Latvian) and sūris (Lithuanian).

The word for cheese in Hindi, Persian, and Turkish sounds like "paneer," which is also the name of a fresh South Asian cheese coagulated with a food acid such as lemon juice.

The expression *cheese it!*, meaning "stop it!" or "be quiet!" was featured in many old movies and comic books, often as "Cheese it, the cops!" It was noted in an 1811 dictionary of British slang and appears to have come from a mispronunciation of "cease." Another slang dictionary, from John Camden Hotten in 1913, cites "cheese your patter" and "cheese your barrikin," both of which basically meant "stop talking."

"Browned off," meaning disgusted or fed up, apparently originated with the Royal Air Force during World War II and referred to rusting of metal; the expression reminded some of browning of cheese when heated, leading to *cheesed off*.

How did *cheesy* turn into a word meaning cheap or inferior? Urdu, now a national language of Pakistan and an official language in five states of India, has a word *chīz* that means "thing." The British picked up on it when they controlled the area starting in the eighteenth century, and by 1818 incorporated it in a phrase "the real cheese," meaning "the real thing." *Hotten's Dictionary* defines cheese and cheesy as "a first-rate or very good article." In the U.S., a good fastball in baseball is sometimes called "hard cheese," with a high fastball being "high cheese" (Spanish players call it "alto queso"). Cheese also features in the expression "the big cheese," meaning a boss or very important person. But

(*continued*)

BOX 1.2 (*continued*)

sarcastic use of the word turned it into a pejorative, with the adjective "cheesy" being recorded in the negative sense in 1896. An unabridged 1940 dictionary has both senses for cheesy: "fine; excellent; smart; esp[ecially], ironically, worthless; good-for-nothing."

Many people's surnames are derived from the trade of their ancestors, and cheesemaking and dairying are no exceptions. The first individuals with the last names Cheeseman and Cheesewright were makers and sellers of cheese. The press used to squeeze the whey from the curds was called a wringer, giving us the last names Ringer and Wringer. Cowherd and Coward come from cow herder and Cowley from cow pasture (cow lea). Byers means cow sheds and Boothby is a farm with byers on it. One derivation of Day is dairy worker. "Wick" meant dairy farm in the thirteenth and fourteenth centuries, giving us Fenwick (dairy farm in the fen), Gatwick (goat farm), and Sedgwick (dairy farm in the reed beds). Cheese is still an English surname; the father of British comedian John Cleese was originally named Cheese, but changed it upon entering the army to avoid ridicule.

BOX 1.3
AMERICAN COWS

There were over six million farms in the United States in 1940, with three-quarters of them having at least one milking cow. Now America has around two million farms, and fewer than six percent of them have milking operations. The reasons for the decreases are:

- Technological advancement, starting with the introduction of electricity in rural areas, which enabled farmers to refrigerate their milk and keep larger quantities of it. Also, machinery has replaced workers, harvesting of crops and milking of animals has improved, the biology of plants and livestock is better understood, and computerized monitoring has given farmers a better idea of what to expect. Fewer farms are feeding more people.
- The shift from forage feeding to a confinement system with feed rations, which has increased milk production per cow and eliminated the time and effort required to shuttle cows between pasture and milking parlor. The amount of milk per cow was just 5,000 pounds a year in the 1940s.
- Specialization, as dairy farming is no longer a sideline on a farm along with several other activities. In the 1940s, about 45% of milk produced was for consumption on that farm, another 43% was sold as a sideline, and 12% was produced on and sold by a dairy-only farm. Now, about 75% of milk produced comes from dairy-only farms.
- The daily grind of having to stay on the farm and take care of cows is not appealing to people who desire easier ways to make a living.
- Economic considerations have forced many dairy farmers out of business. Almost 90% of dairy farms are family-owned, and some of them lack the money

BOX 1.3 (*continued*)

to withstand fluctuations in milk price. When milk prices are low and feed and fuel prices are high, some farmers are forced to sell their cows and equipment and close down. Others prosper by making farmhouse cheese, a value-added product.

The number of milking cows in the United States has dropped from 21,994,000 in 1950, to 10,799,000 in 1980, to 9,197,000 in 2011. The average number of cows per herd has grown from 6, to 32, to 179 in that span. Although the amount of milk produced by American cows continues to go up (it was over 196 billion pounds in 2011), the number of farms with a permit to sell milk has dwindled dramatically over the past twenty years, from more than 130,000 to less than 52,000.

Which state has the most dairy farms? That would be Wisconsin, with 12,100. Pennsylvania is a distant second, with 7,240. Table B1.3 shows the 11 states with at least 1,000 dairy farms as of 2011:

California averages a whopping 1,061 cows per herd, while the other states listed above average between 61 and 171. California, Wisconsin, and New York are the top three states in cow population, with Idaho (580,000 cows in 575 herds) fourth, Pennsylvania and Minnesota fifth and sixth, Texas (435,000 cows in 590 herds) seventh, Michigan eighth, New Mexico (333,000 cows in just 140 herds) ninth, and Ohio tenth. Farmers can have many cows in a herd if they have the land available, resulting in growth in nontraditional dairy areas with open space. Among the fifty states, Idaho ranked twentieth in milk production in 1975, and New Mexico was forty-first; both states have since become heavily involved in dairy farming.

BOX 1.6

MILK FROM OTHER SPECIES

Although all mammals produce milk, cheese cannot be made easily, or at all, from some species. Camels have historically supplied milk to North Africans and Asians, but it is difficult to coagulate the milk into a curd, and much of the protein and fat are lost in the whey, so cheesemaking is not economical. Central Asians ferment horse milk into the alcoholic drink *kumis*, but the milk lacks κ-casein and will not coagulate at all. Some mammals, such as zebras, cannot be domesticated, while others, such as rabbits, are too small to produce much milk.

Can you make cheese from human breast milk? That is the strangest question I have ever been asked about cheese, and it's been asked several times. The answer is no, because the milk won't coagulate properly. Breast-feeding mothers often have milk left over, and people sometimes wonder what can be done with it. Perhaps make some sort of cheese from it? Daniel Angerer, chef of Klee Brasserie in New York City, prepared and served some in his restaurant in 2010 before the Health Department asked him to please stop it. It turns out that his recipe called for 2 cups of breast milk and 2 cups of conventional milk per batch. Breast milk alone can't be made into cheese because it contains too little protein (only 1%), and only some of the protein is casein. In early lactation, 90% of the proteins are whey proteins, decreasing to 50% in late lactation. Research in our laboratory some years ago demonstrated that human milk will not form a curd.

A French web site, Le Petit Singly, advertises that they have made cheese from "breast milk of woman" since 1947. If you try to order some online, you will be sent to a page asking you if you are crazy. They admit on that page that it is a hoax, though some news outlets have reported on the "company" without discovering it is a joke.

If you do have surplus breast milk, it is best to donate it to a breast milk bank, where it will be used to feed infants in neonatal intensive care units.

BOX 2.2

MILK STANDARDS

All dairy farmers have to abide by quality standards for animal health, facility cleanliness, milking procedure, equipment cleaning procedures, water quality, and waste disposal. No drug residues or added water are allowed. The milk is inspected regularly and judged to be either Grade A (fluid grade) or Grade B (manufacturing grade). The liquid milk purchased and consumed in the United States is subjected to relatively little processing, so its standards therefore have to be very high. About 97% of American cow's milk is Grade A, which meets these highest standards. Grade B milk is not consumed until after it has been converted into cheese, butter, or milk powder; the processing involved in making these products eliminates any dangers from lower-quality milk. Grade B milk cannot be used for fluid milk, but Grade A can be used for making cheese and the other products.

Milk normally contains relatively few bacteria as it leaves the cow, but the number will grow quickly without refrigeration. The storage temperature and resulting bacterial count are the primary difference between the two grades. Grade A milk is cooled to a maximum of 50° within 4 hours of the start of milking, and to a maximum of 45° within 2 hours of the completion of milking. Less than 100,000 bacteria per milliliter (3 million per ounce) of Grade A milk is allowed. Grade B milk is cooled to a maximum of 50° unless it is taken to the processing plant within 2 hours; if stored in a tank, it is cooled to 40° within 2 hours and maintained at 50° or less. The maximum number of bacteria in Grade B milk is 500,000 per milliliter.

(*continued*)

BOX 2.2 (*continued*)

Grade B milk bottle cap from the 1930s.
Source: Author's collection.

BOX 2.3
HOMOGENIZATION

The fat droplets in raw milk are various sizes (1–15 micrometers), and may be considered as dispersed throughout skim milk. Milk fat is less dense than water and therefore rises to the top. In homogenization, milk is forced through a small orifice at high pressure (2000–4000 psi, or 13.8–27.6 megapascals), reducing the size of the fat droplets to 1–2 micrometers, making them more uniform. The milk is sent through twice to prevent the droplets from clumping. By doing this, the milk fat globule membrane that surrounds each droplet is stripped away. Proteins in the milk then cover the droplets, making them denser and less likely to rise to the top of the milk container. Homogenization started to become popular in the 1930s and was almost universal by the 1960s; prior to that, milk was delivered to homes with a cream layer on top.

Cheesemilk is not usually homogenized because the reduction in size of the fat globules alters the texture and functionality of the resulting cheese. Smaller globules are trapped in the protein matrix and are not released during heating, which prevents melting. Removal of the milk fat globule membrane leaves the globules susceptible to a higher level of degradation, which may lead to rancid flavors. Blue,

BOX 2.3 (*continued*)

Feta, and cream cheese are often made from homogenized cow's milk since it leads to a whiter color, increased breakdown of fat (desirable in these varieties), and a smoother texture. Other varieties come out with a poor texture and a moisture content that is undesirably high when the milk is homogenized. Queso Fresco is supposed to be a non-melting cheese, so the milk is homogenized to prevent melting.

BOX 2.4
RAW MILK CHEESE

For many years, authorities such as the Centers for Disease Control (CDC) and the U.S. Food and Drug Administration (FDA) have feared that raw milk can be dangerous because there is no pasteurization step for killing pathogens that might be present. Illnesses caused by *E. coli* O157:H7, *Campylobacter*, and *Salmonella* have been linked to consumption of raw milk and products such as raw milk cheese. Listeriosis, an uncommon but often fatal illness caused by *Listeria monocytogenes* may also be correlated with raw milk and cheese made from it. Interstate sales of raw milk have been forbidden in the United States since 1982, and 20 states will not allow sales at all. Retail store sales are currently legal in 12 states, and on-farm sales are allowed in another 13 states. The remaining states have other regulations such as "cow shares," which entail part-ownership of a cow and the right to any raw milk coming from her. Much raw milk comes from certified dairies that have to undergo stringent sanitation requirements and testing.

In the U.S., cheese made from raw milk must be held for at least 60 days. Any pathogens in the milk should die out during this time, and the acidity generated by the cheesemaking process will prevent pathogens from the environment from taking hold. Bacterial contamination from just one cow can spread through an entire vat of milk and then to a production run of raw milk cheese, which is why the rules exist. Raw milk cheeses from outside the U.S. must also follow this requirement or they cannot be imported. The CDC and FDA recommend that children under five, pregnant women, and people with immunodeficiency problems or chronic disease should not consume raw milk products.

Many cheese connoisseurs disagree with these regulations, since pasteurization not only kills off pathogens but also the naturally occurring bacteria that contribute to flavor and might convey health benefits. They often refer to pasteurized milk cheeses as "dead cheese." A test of 890 attendees at a recent Oregon State University food festival showed that 426 people preferred the raw milk version of a cheese, 319 preferred the pasteurized version, and the rest had no preference or could not tell the difference. The study also showed that some consumers consider raw milk cheese to be a delicacy and are willing to pay more for it.

TABLE 2.1

Classes of cheese

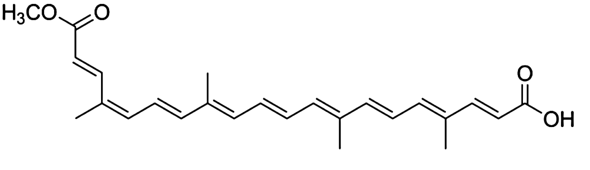
Class (alternate name)	Varieties commonly sold in the U.S.
Fresh soft	Cottage, cream
Whey	Ricotta
Pickled (brined)	Feta
Stretched curd (pasta filata)	Mozzarella, Provolone
Surface mold (bloomy rind)	Brie, Camembert
Smear-ripened (washed rind)	Limburger, Brick
Interior mold (blue-veined)	Blue, Stilton
Cheddared (English style)	Cheddar, Cheshire
Washed curd	Gouda, Colby
With eyes (Swiss type)	Emmental, Gruyère
Very hard	Parmesan, Romano

BOX 2.5
WHY IS CHEESE YELLOW?

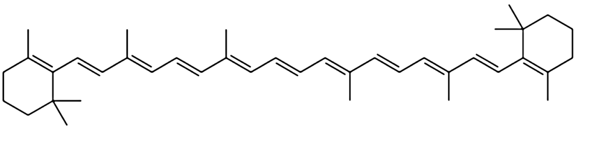
"They had but one last remaining night together, so they embraced each other as tightly as that two-flavor entwined string cheese that is orange and yellowish-white, the orange probably being a bland Cheddar and the white . . . Mozzarella, although it could possibly be Provolone or just plain American, as it really doesn't taste distinctly dissimilar from the orange, yet they would have you believe it does by coloring it differently."
—MARIANN SIMMS, 2003 winner of the Bulwer-Lytton Fiction Contest for writing intentionally bad opening sentences to imaginary novels

The color of food influences our perception of it. Studies have shown that color affects our expectations of the flavor of food, more than labeling and even its actual taste. When a transparent version of a popular cola beverage was introduced in 1992–1993, regular drinkers of the normally colored soda did not like it, even though the flavors were identical. Consumers anticipated the flavor from the soda's appearance, and were thrown off when they drank it. The product was discontinued.

Cheese is no exception to the association between color and flavor. Some people perceive orange Cheddar to be richer than yellow Cheddar, though their fat contents and flavors are identical, so cheesemakers add annatto to color it. The major component of annatto is bixin (the scientific name of the achiote tree, the source of annatto, is *Bixa orellana*). Much of the molecular structure of bixin is similar to that of β-carotene, the compound that gives carrots their orange color. Cows transfer carotenoids (β-carotene and related compounds) from their diet to the milk, where they bind to the fat. The fat content of milk is less than 4%, the carotenoid concentration is less than 0.1%, and the fat globules are surrounded by casein, so the yellow color is not visible. Most of the whey is lost during cheesemaking, causing the fat and carotenoid contents to increase, and the casein network loosens up to reveal the fat, to the point where the resulting cheese takes on a yellow color. Goats, sheep, and water buffalo do not pass carotenoids to milk (converting it to vitamin A instead), and their cheese is white. Consumers expect some cow's milk cheeses to be white or light yellow, resulting in the addition of titanium dioxide, a widely-used white pigment.



Bixin



β-carotene

BOX 2.7
NSLAB

This acronym stands for *non-starter lactic acid bacteria*. These are the bacteria that are not inactivated by pasteurization, or otherwise find their way into the milk and curd. Some NSLAB are resistant to the cleaning and disinfecting agents used in the cheese plant, and have been isolated from the equipment, floors, and drains. NSLAB may also be airborne, originating from the environment around the plant. NSLAB proliferate during ripening, eventually becoming dominant in the cheese. At the start of ripening, a typical cheese may contain a billion colony-forming units of starter bacteria per milliliter of cheese. During the first month, that number may decrease to ten million, allowing NSLAB to increase. They can provide typical flavors, atypical but desirable

BOX 2.7 (*continued*)

flavors, and off-flavors. Some 60 *Lactobacillus* species are known, of which about a dozen have been detected in cheese as NSLAB.

The presence of NSLAB, molds, and other microorganisms that are not intentionally added brings some uncertainty to the cheesemaking process. Consider the story of Liederkranz cheese, which is an American version of the European cheese Limburger. Liederkranz was developed in Monroe, New York, in 1891 by a Swiss cheesemaker named Emil Frey, who went on to create Velveeta 27 years later. Frey named the cheese after the Liederkranz ("wreath of song") singing society. The Monroe Cheese Company, the only firm to manufacture this variety, moved to Van Wert, Ohio, in 1926. Frey, his assistants, the starter cultures, and the original equipment all moved, too. The wooden shelves used to store the cheese stayed put, however. When they tried to make the cheese at the new place, it did not turn out properly. Various changes were attempted, but the original could not be duplicated. Finally, they smeared the new tile walls with the residue from the wooden shelves from the old plant. Nobody would ever do that sort of thing nowadays, but the cheese came out perfectly. Some of the microorganisms (probably Coryneform bacteria) floated from the wall and into the vats, the same way they wafted from the shelves and into the vats at Monroe. It was then that the cheesemakers realized that their product was not just affected by what they add, but also by things they don't add.

BOX 2.8
GREEN CHEESE AND GREEN MEAT

> *"The moone is made of a greene cheese."*
> —THOMAS HEYWOOD, *Proverbs*, 1546

When you say that the moon is made of green cheese, you are not claiming that Earth's satellite is green in color. You are actually comparing the color and shape of the moon to a fresh or unripened cheese: a green cheese is an unaged one that is white to light yellow. The expression originated in England long before Heywood recorded it.

But cheese can turn processed meat green. When packaging some cheeses with cured meat inside a sandwich, the meat begins to turn green within a few hours or days. The culprits are starter bacteria that produce H_2O_2, hydrogen peroxide. H_2O_2 resembles H_2O, water, but the extra oxygen atom makes it highly reactive.

Meat is cured by adding sodium nitrite, $NaNO_2$, either in pure form or by adding celery juice or celery powder, which are naturally high in it. The $NaNO_2$ reacts with myoglobin, the protein that gives muscle its red color, and when heated forms nitrosohemochrome, the pink pigment in cured meat. H_2O_2 reacts with this compound, creating green-colored products. A commonly used starter culture, *Leuconostoc mesenteroides*, is a

(*continued*)

BOX 2.8 (*continued*)

very effective producer of H_2O_2, and another popular starter, *Lactobacillus delbrueckii* subspecies *bulgaricus*, is also a good H_2O_2 generator. At least one nonstarter lactic acid bacteria (*Weissella paramesenteroides*, found in grasses and silage) also forms H_2O_2. These bacteria tolerate NaCl, $NaNO_2$, heat and smoke, and the H_2O_2 they generate remains even if the bacteria are killed during processing. Changing the cheese used in the sandwich will eliminate the green meat problem.

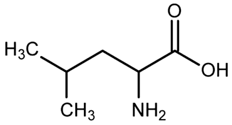
BOX 2.10
WHEY UTILIZATION

The whey from renneted cheese curd, called sweet whey, used to be discarded, fed to pigs, or spread on fields as a fertilizer. In 1942, one company poured their whey down a deep abandoned well on their property, apparently deciding that where there's a well, there's a whey. The trapped whey, under pressure, eventually developed enough gas to blow off the top of the well.

Whey is now too valuable to toss out. By allowing it to acidify and heating it nearly to boiling, the whey proteins coagulate into a fine curd that is made into Ricotta or Requesón. Boiling whey with milk and cream causes the lactose to caramelize, producing the Norwegian Geitost. Many Mozzarella plants also have a Ricotta operation. But the real money-making use for whey is in the manufacture of whey powders. After the fat is removed, whey is filtered under pressure through microfiltration membranes that catch bacteria and casein, and the whey proteins are retained by an ultrafiltration membrane. After drying to remove the water, whey protein concentrate (20%–89% protein) or whey protein isolate (at least 90% protein) is obtained. Whey powder is used in many foods because it foams well, provides a golden surface on baked goods, binds water, and adds nutritive value. Our laboratory has used whey protein powder to produce high-protein cheese puffs.

BOX 2.10 (*continued*)

In Chapter 1, we mentioned that proteins come in the form of amino acids linked together. Three amino acids, valine (shown below), leucine, and isoleucine, have branches or forks. These branched-chain amino acids are found in great numbers in muscle tissue, and fuel working muscles while stimulating the generation of protein. Whey proteins are about two-thirds β-lactoglobulin, one-fourth α-lactalbumin, and one-twelfth serum albumin, and all of these contain 19%–25% valine, leucine, and isoleucine. These proteins are rapidly absorbed into the body. Nutrition and health food stores sell canisters of whey protein powder to body-builders and athletes. People lose muscle mass as they become older, and whey protein is helpful for reducing frailty.



BOX 2.11
WHY DO FRESH CHEESE CURDS SQUEAK?

Some small cheese companies, especially in the northern U.S., sell bite-size cheese curds that have not been pressed or aged. These curds will emit a squeak when you bite into them, especially if they are less than a day old. The casein network in unpressed fresh curd has not knitted into a compact structure, but rather is porous with plenty of air trapped inside. The wet, elastic curd vibrates when you put your teeth through it, and this vibration is at a frequency in the audible range.

Cheese curds.
Source: Author's collection.

You can observe a similar effect by pulling your wet hair between your fingers after shampooing it. The detergent in the shampoo removes the oil from your hair, so your fingers don't glide smoothly, but "skip" along wet strands. The outer surface of hair is also protein, primarily keratin, but this time it is your fingers that do the vibrating.

School students used to hear a high-pitched squeal when the teacher ran a piece of chalk across the blackboard in a certain manner. (If you are under 25, ask your parents what a blackboard is). When the chalk was positioned at a particular angle and gripped the right way, it would skip rapidly. The resulting high-frequency noise would reverberate in the ear canal and produce a physical reaction in many students.

BOX 2.12

GIANT CHEESES

> *"He has bitten his way into the Big Cheese."*
>
> —O. Henry, *The Unprofitable Servant*, 1911

Giant cheeses have been manufactured for publicity or special occasions. A Cheshire cheese weighing 1,235 pounds and using the milk of 900 cows was made in Cheshire, Massachusetts, sent by sleigh for 500 miles to Washington, D.C., and presented to President Thomas Jefferson on January 1, 1802. Inscribed with "Rebellion to tyrants is obedience to God," it was called the Mammoth Cheese due to the discovery of mammoth (now known to be mastodon) bones the year before. Cautious of accepting free gifts, Jefferson paid $200 for it and displayed it in the East Room for a year. Not to be outdone, supporters of President Andrew Jackson made a 1,400-pound cheese for him in 1837. But the largest cheese prior to the twentieth century was a 22,000-pound Cheddar made in Perth, Ontario, for the 1893 Columbian Exposition in Chicago. "The Canadian Mite" was made from 27,000 gallons of milk from 10,000 cows that were milked by more than 1,600 "maids." The curd came from 12 factories over a three-day period and was emptied into a hoop at the local railway station. The curd was pressed with 200 tons of pressure after each filling, forming a cheese 9 feet in diameter and 6 feet high.

A larger cheese was made for the Wisconsin Pavilion at the 1964–65 World's Fair in New York. The 34,591-pound Cheddar required 42,500 gallons of milk from 16,000 cows. Twenty men worked around the clock for 43 hours to make the cheese, which measured 14½ feet by 6½ feet by 5½ feet. The current record-holder is a 56,850-pound Cheddar made in Oregon by the Federation of American Cheese-makers in 1989.

BOX 3.1
WHAT CAN GO WRONG?

> *"It's not really a cheese for eating—it's more for encasing in concrete and dumping in the ocean a long way from civilization."*
>
> —JASPER FFORDE, *Thursday Next: First Among Sequels*, 2007

Any number of factors can lead to a less-than-ideal cheese. When a cheesemaker sees that things are going wrong, some alterations in the procedure are made to increase the chances that the batch, or future ones, won't have to be discarded. The following table (B3.1) shows common problems for hard and medium-hard cheeses and the some of the procedures that may be used to fix them. The steps in italics are usually the most effective.

Other problems can also occur, such as equipment failures and power outages. So can natural disasters: on May 20, 2012, a strong earthquake and two aftershocks struck the region of Italy that produces Parmigiano Reggiano, the name-protected version of Parmesan. A total of 633,700 wheels were being aged at the time, and some 300,000 of them in twelve facilities were damaged when they tumbled onto the floor after the shelves fell over or collapsed. The wheels that were aged more than a year were chopped into pieces and sold. But damaged wheels less than a year old had to be sent away without being labeled as genuine Parmigiano Reggiano. They found use as ingredients in other products, but the financial loss from the inability to use the official designation amounted to millions of dollars.

BOX 3.1 (*continued*)

TABLE B3.1

Cheesemaking problems and solutions

Problem	Solution	Steps to take
Cheese is too soft	Increase expulsion of whey	Raise calcium content by adding calcium chloride to the milk Cut curd into smaller cubes *Raise cooking temperature* *Maintain temperature during final stirring* Raise pressing time or temperature
Cheese is too hard	Decrease expulsion of whey	Add water to milk or during cooking Cut curd into larger cubes *Lower cooking temperature* *Cool curd cubes for a few minutes before stirring ends* Add more NaCl to whey, causing curd cubes to swell Reduce pressing time or temperature
Cheese is too acidic	Decrease acid production	Reduce amount of starter culture *Add water to milk or add more water during cooking* Raise cooking temperature or start cooking early to slow lactic acid development
Cheese is not acidic enough	Increase acid production	Raise amount of starter culture Add less water *Reduce cooking temperature* Cool curd cubes for a few minutes before stirring ends
Insufficient microbial activity during ripening	Increase microbial growth	Increase amount of starter culture *Increase storage temperature* Increase storage humidity

BOX 4.1
THE DIFFERENCE BETWEEN CHEESE AND YOGURT

Like cheese, yogurt ("to thicken" in Turkish) is produced using starter cultures, usually *Lactobacillus bulgaricus* and *Streptococcus thermophilus* and sometimes including bifidobacteria and *Lactobacillus acidophilus*. Unlike cheese, the milk is heated to 185° for 30 minutes or 200° for 10 minutes, which kills off any pathogens and causes the milk protein to denature, or fall apart. By doing this, the milk thickens instead of forming curds. The starter is added after the milk is homogenized and cooled to 110°, and the temperature is held there for 2–3 hours. The result is a gel with a pH of 4.5. No effort is made to remove whey, so fruit and flavor are often added to neutralize some of the tartness.

Yogurt production was exclusively artisanal until 1919, when Isaac Carasso, whose oldest son was named Daniel, began industrial manufacture of yogurt in Barcelona, Spain. He named the company *Danone*, Catalan for "little Daniel." The son took over the company in the late 1930s, moved it to New York in 1942, and changed the American version of its name to Dannon.

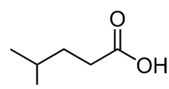
Strained (or Greek) yogurt is strained to remove whey, producing a thicker product. A pound of milk is needed to make a pound of regular yogurt, but four pounds are required to obtain a pound of strained yogurt. *Labneh* (from a Semitic word for "white") is a similar product popular in the eastern Mediterranean.

BOX 4.2
STABILIZERS

Xanthan gum, guar gum, and locust bean gum (also called carob bean gum) are polysaccharides, a carbohydrate in which a section of the molecule repeats itself many times to form a long chain. Xanthan gum is isolated from the coat of the bacterium *Xanthomonas campestris*, which may be grown in whey, where it metabolizes lactose. Guar gum is extracted from guar beans, a legume grown mostly in India. Locust bean gum comes from seeds of the carob tree, found in the Mediterranean region. These gums are effective thickeners—a small amount greatly increases the viscosity of a liquid (water has low viscosity and ketchup has high viscosity). They also exhibit shear thinning, which means that chewing or mixing it lowers its viscosity, and when the chewing or mixing stops, the viscosity recovers. They are used in salad dressings for this reason since it causes the liquid to flow easily when the shaken and poured, and then thickens again and sticks to the salad. Xanthan and guar gums control the viscosity of cottage cheese dressing. All three gums stabilize cottage and cream cheese by coating the fat droplets and keeping them from separating out.

BOX 5.5
STINKY PLANTS

Many plants give off pleasant (to us) aromas to attract certain pollinators. Others let loose with odors that may charitably be called “disagreeable.” Notable among these are some plants in the Araceae (or Arum) family, including species of Amorphophallus (Greek for “misshapen penis,” referring to the spike projecting from it). The smells coming from these tubers are described as “dung,” “nauseating gas,” “rancid, rotting meat”—and strong cheese. *Amorphophallus elatus* in particular produces a powerful cheesy odor, and the only compound responsible is isohexanoic acid, also called isocaproic acid:

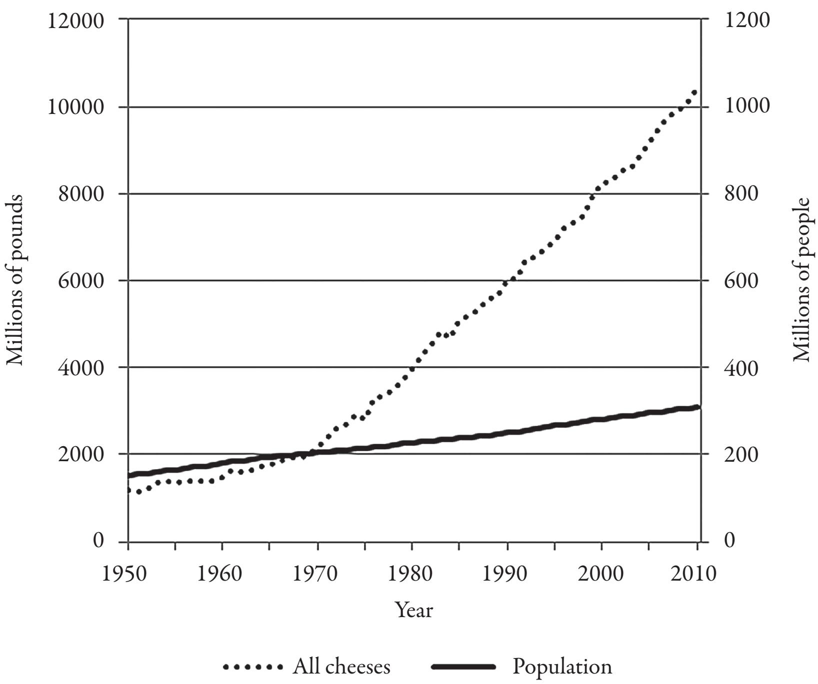


Isohexanoic acid has a pungent cheese aroma. Isovaleric acid, which has one less carbon atom, is found in several species of foul-smelling flowers. Flies are the pollinators of these plants, so we may assume they, like some people, are attracted to the odor of cheese. A couple of other Amorphophallus species generate cheesy fragrances, which have attributed to combinations of acetic acid, dimethyl disulfide (which we will meet in Box 7.1), ethyl acetate (Box 8.3), and 2-heptanone (Box 9.2).

Arum plants.
Source: Author’s collection.

BOX 6.2
PRODUCTION

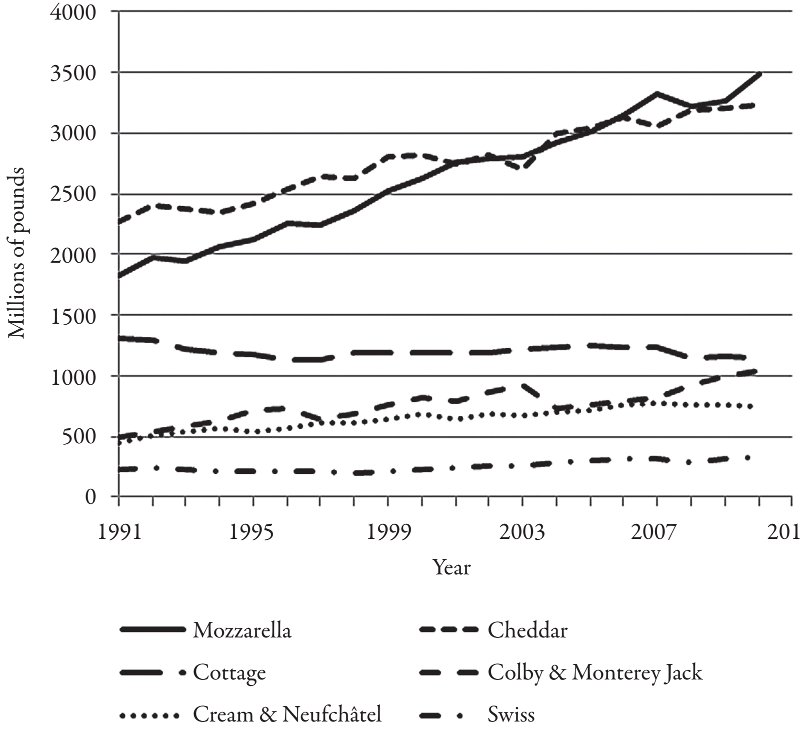
The production of cheese in the United States has increased faster than the population, as you can see in the chart below. In the 1950s and 1960s, Americans were consuming less than 10 pounds of cheese per capita, so there were more than ten times as many people as pounds of cheese produced. In 1970, there were 2,201,430,000 pounds of cheese made for 205,052,000 people, or 10.7 pounds per person. Cheese production and consumption has increased dramatically since then: in 2011, manufacturers produced 10.609 billion pounds for 311.6 million people, or 34 pounds per capita. About 95% of this cheese is being eaten by American consumers. The United States exported 494 million pounds in 2011 and imported 313 million pounds.



Cheese production in the United States by year.

When you ask Americans to name a variety of cheese, many will choose Cheddar; and if you asked them to draw a picture of cheese, most will depict Swiss. But the most popular variety in the U.S. for the past few years has been Mozzarella, mainly due to the increasing popularity of pizza and string cheese. The chart below shows that production of Mozzarella first surpassed that of Cheddar in 2001 and has stayed ahead every year since 2006. Cottage cheese, including creamed, dry curd, and lowfat, ranks third. The USDA reports Colby and Monterey Jack together, and they combine for fourth place. Cream and Neufchâtel are fifth, and Swiss is sixth.

BOX 6.2 (*continued*)



Cheese production in the United States by variety.

The top cheesemaking state is Wisconsin, with 2.637 billion pounds in 2011, followed by California with 2.245 billion pounds. Idaho and New Mexico have built large cheesemaking industries, and check in at third and fourth place with 841 and 744 million pounds, respectively. New York (741 million pounds), Minnesota (603 million), and Pennsylvania (412 million) are the other states producing more than a quarter billion pounds of cheese a year.

BOX 7.2
TASTE

The gustatory sense is composed of five basic tastes, and possibly a couple of others. Bitter, sweet, sour, and umami can arise when proteolysis has proceeded to the point where casein have broken down into amino acids. Despite what was earlier believed, receptors for taste are found throughout the tongue and are not confined to specific areas.

Bitterness is the most sensitive of the five tastes and is commonly encountered in coffee, citrus peel, and tonic water, which contains the notably bitter compound quinine. Many toxic plants contain bitter compounds, but rejection of foods for bitterness by animals and humans does not depend on whether response the food is harmful or harmless. Rather, it depends upon how many bitter and potentially toxic compounds are in their diet. Carnivores, who rarely encounter toxic plants, have a low bitterness threshold and a low tolerance for poisonous compounds, whereas grazers, who cannot limit their dietary choices as completely, have a high threshold and tolerance. A number of amino acids found in cheese have a bitter taste: arginine, isoleucine, leucine, methionine, phenylalanine, tryptophan, tyrosine, and valine. These are not nearly so strong as other flavor compounds, and they must be present at hundreds of parts per million to be detectable. Oleic acid in cheese appears to mask bitterness in cheese by bonding with bitter compounds.

Sweetness is not only related to sugar, but also to aldehydes, ketones, and other compounds containing the C=O group. These include the amino acids alanine, glycine, serine, and threonine. Proline is sweet and bitter. These can't be detected unless they are at a level of tenths of a percent.

Sourness is a measure of acidity. Citrus and some other fruits are naturally sour, and so is cheese when the pH is low. Aspartic acid and glutamic acid are amino acids with sour tastes. These amino acids can be detected at 30–50 ppm.

Saltiness is related to NaCl and KCl, potassium chloride. KCl is used as a salt substitute for people who are reducing their intake of sodium, but the pure compound is bitter and imparts a metallic taste to some people.

Umami, a savory impression imparted by monosodium glutamate (MSG), comes from the glutamate form of glutamic acid. It wasn't identified until 1908 and was not officially recognized as a basic taste until the 1980s. Umami is described as stimulating the oral cavity and the tongue, on which there is a slight furriness. Umami enhances the flavor of food, which is why some chefs add MSG to their dishes, and it is a noted feature of ripe tomatoes, soy sauce, and aged cheese.

Two other sensations that may be basic tastes are fattiness and calcium. A particular gene in mice and rats allows them to detect lipids, which may mean that humans also possess a fat receptor. Michael Tordorf of Monell Chemical Senses Center in Philadelphia reported at an ACS meeting in 2008 that mice have a calcium receptor that helps control their calcium intake, and that humans may have one also. When I asked him later what calcium tastes like, he replied that it was "calciummy."

BOX 8.1
LIMBURGER IN POPULAR CULTURE

In the mid-1800s, German and Belgian immigrants began to arrive in the United States with a taste for Limburger, which they enjoyed with raw onions and mustard in rye bread sandwiches accompanied with cold beer (to this day, aficionados claim this is the best way to eat it). By the 1880s, comedians began to associate Limburger with accented immigrants. Americans picked up on the idea that Limburger was a highly odiferous food that can be the butt of jokes, and have never let it go. In Mark Twain's 1882 tale "The Invalid's Story," the narrator shares a railroad car with another man, a Limburger cheese, and a pine box they thought contained a recently deceased man. The smell from "the deadly cheese" overpowers them, and the story concludes: "My health was permanently shattered; neither Bermuda nor any other land can ever bring it back to me. This is my last trip; I am on my way home to die." The first record ever sold by

Limburger cheese.
Source: Author's collection.

BOX 8.1 (*continued*)

the Victor Talking Machine Company was "Limburger Cheese" in 1901, a monologue by comedian Burt Sheppard. He relates that, as a boy, he bought some Limburger, placed pieces in his parents' pockets before they went to church, and watched as the congregation gradually fled. In the 1918 movie *Shoulder Arms*, Charlie Chaplin plays a World War I soldier who receives Limburger in a package from home, dons a gas mask, and lobs it into a trench full of German soldiers to force their surrender.

When Prohibition was enacted in 1920, workers could no longer patronize bars to eat their Limburger sandwiches, and the popularity of the cheese never recovered. It suffered a further blow in 1935 when newspapers revealed that Limburger was the favorite snack of Lindbergh baby kidnapper Bruno Richard Hauptmann. Over 6.5 million pounds of Limburger were produced in America in 1951, but it is now made in this country by only one company, in Monroe, Wisconsin, which turns out less than 650,000 pounds a year. Brick cheese, which gives off a less powerful aroma and has been called "the married man's Limburger," is manufactured at ten times that rate.

BOX 9.1
PENICILLIN

Bread with blue mold on it was used to treat open wounds in Europe in the Middle Ages. Nobody knew at the time that the mold contained species of Penicillium (from the Latin *penicillus*, “paintbrush,” referring to its appearance under the microscope), which secrete a compound that interferes with production of bacterial cell walls. The bacteria die as a result, making Penicillium extract an effective treatment for many infections. But the mechanism of disease transmission was unknown until the late nineteenth century, and people died of infectious diseases in numbers that would be alarming to us today.

The use of penicillin as an antibiotic for treating bacterial infections was pioneered by Alexander Fleming, a bacteriologist working at St. Mary’s Hospital in London. Sixteen years after the discovery, he told a story that is now famous: in the fall of 1928 he noticed that a staphylococcus culture in a petri dish in his laboratory was killed by *Penicillium notatum* spores that had floated in through an open window while he was on vacation. Fleming realized that the mold could be useful instead of a nuisance, identified the antibacterial agent, and named it penicillin. In reality, the events could not have taken place as he remembered, since no bacteriologist would have an open window through which contaminants could drift in (his small laboratory window was never opened anyway), and the Penicillium would have overwhelmed the culture in the dish and not just established a few colonies, as he later recalled. The Penicillium probably came from the lab below Fleming’s (where the same strain was grown), and he performed an experiment on it as part of a study on something else (he mentioned this experiment in his notebook weeks after his vacation, but wrote nothing about the staphylococcus in the petri dish). At any rate, Fleming set out to isolate penicillin in a form and quantity suitable for administering to people, but failed. Fortunately, Howard Florey and Ernest Chain at England’s Oxford University succeeded in converting penicillin into a stable powder in 1940.

The next challenge was scaling up the process. Great Britain was involved in World War II by then and did not have the resources to pursue penicillin manufacture, so the scene shifted to America. Originally, the mold was grown as a mat atop a nutrient solution. Difficulties with contamination and isolation resulted in enough penicillin for treatment of just one case by March 1942. Scientists at the USDA’s Northern Regional Research Laboratory (now the National Center for Agricultural Utilization Research) in Peoria, Illinois, began pumping air into deep vats containing *P. notatum* suspended in corn-steep liquor, a non-alcoholic byproduct of wet-milling corn. This process was far more effective, and in July 1943, the War Production Board asked for mass-production of penicillin to begin as soon as possible. The Peoria lab began a search for the Penicillium species that would grow best in the huge vats. Since Penicillium grows in soil, U.S. Army pilots around the world sent in dirt samples to be tested. Peoria residents and lab employees were encouraged to donate moldy household objects. One lab technician, Mary Hunt, was assigned the task of visiting area groceries to locate spoiled

BOX 9.1 (*continued*)

food, earning her the nickname "Moldy Mary." The species that grew best, *Penicillium chrysogenum*, was found by Hunt on a cantaloupe from a Peoria market, and was used in the research. The process was successfully scaled up by several pharmaceutical firms, and the United States had 2.3 million doses in time for the Normandy invasion on D-Day, June 1944. The drug was available to the general public by war's end. Fleming, Florey, and Chain never patented penicillin and earned no royalties on it, though they did share in the 1945 Nobel Prize in Physiology or Medicine.

Penicillin was credited with saving countless lives and limbs during the war as it prevents gangrene, a common battlefield infection, and destroys other bacteria that cause disease. It is still widely used as the first line of defense against many dangerous bacteria.

BOX 9.4
ANOTHER USE FOR FUNGUS

Microorganisms can be used for various purposes, not just fermenting food. For instance, a team in Germany fashioned a cleaning agent using *P. roqueforti* mounted on plastic. The device consisted of a three-layer sandwich: a plastic base layer used as a support, the living layer consisting of the fungus habitat, and a porous cover membrane for protecting the living layer from its surroundings while allowing gases and nutrients to pass through. The cover also protects the human user from the fungi. Under proper environmental conditions, the fungus remains in a nearly dormant state for weeks at a time until coming in contact with a nutrient source such as bacterial contamination or spilled food. The *P. roqueforti* consumes the nutrient while staying in its habitat and then reverts to its near-dormant condition. This arrangement can be used in a hospital setting since the cover allows the living layer to be active even if in contact with disinfectants or detergents. The research team speculates that antibiotic, self-sterilizing units will eventually be developed from this technology.

BOX 10.1
CHEDDAR GORGE

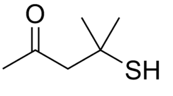
Cheddar Gorge is a popular tourist attraction and considered one of England's greatest natural wonders. The gorge was formed by a surface river cutting into the limestone over the past 1.2 million years. Many caves are there, and the two largest, Cox's Cave and Gough's Cave, are open to the public. The gorge is home to several rare or unique species of plant life.

Great Britain's oldest complete human skeleton, dating back to around 7150 BC, was found in Gough's Cave in 1903. Nicknamed "Cheddar Man," he was an adult male who was apparently killed—the side of his skull has a hole in it. In 1997, Oxford University researchers led by Bryan Sykes extracted mitochondrial DNA (mtDNA) from one of the molars. DNA carries all genetic information for an individual; mtDNA comes from cellular power plants, the mitochondria, and is inherited only from the mother. Cheddar Man's mtDNA was compared to scrapings from the cheeks of 20 local residents, and one local teacher, who was born 15 miles away in Bristol, was a match. He and Cheddar Man therefore both had a common female ancestor.

BOX 10.2
MEOW

"It's a Cheshire-cat," said the Duchess, "and that's why."
—LEWIS CARROLL, *Alice's Adventures in Wonderland*, 1865

2-Mercapto-2-methylpentan-4-one is both a sulfur-containing compound and a ketone, with this structure:



It has been found in cheese, black currants, and other foods. It is also a breakdown product of a longer molecule, felinine, an amino acid found in the urine of male domestic cats. Felinine is presumed to be involved in the production of pheromones, which the cat uses to mark territories in order to attract females and repel other males. Tomcats excrete four times as much felinine as female cats or castrated male cats. 2-Mercapto-2-methylpentan-4-one helps impart the characteristic odor to tomcat urine and is responsible for the catty odor that aged cheese sometimes has. In cheese it probably arises from the breakdown of methionine in casein and may be considered a desirable flavor in Cheddar. In fact, at least one noted manufacturer deliberately adds an adjunct culture that produces 2-mercapto-2-methylpentan-4-one in one of its Cheddar brands. Cheese tasters and graders will often say "meow" when they encounter this aroma in a product.

BOX 11.1
CANNONBALLS

> *"I was blown up while we were eating cheese."*
>
> —ERNEST HEMINGWAY, *A Farewell to Arms*, 1929

In the days of sail, iron cannonballs were fired from close range at enemy ships to damage their wooden hulls. Edam's spherical shape inspired Commodore John H. Coe of the navy of Montevideo, Uruguay, to use the cheese as actual cannonballs when they ran out of ammunition while battling Admiral William Brown's force from Buenos Aires in 1841. The Edam was rock-hard, and the first lieutenant said that he broke the carving knife trying to cut it. One cheese shattered into dangerous splinters upon striking the main mast, another flew in through a porthole and killed two men before fragmenting, and several others ripped through the sails. Brown retreated.

A 2009 episode of the *Mythbusters* television show attempted to show whether or not a cheese fired from a cannon at 30 feet (a typical distance in nineteenth-century sea battles) could put a hole in a sail. The Edam they used was too soft and simply bounced off the sail without damaging it. A smoked Gouda, which was hard and brittle, fragmented upon exiting the cannon barrel. They also tried a hard Spanish goat cheese, Garrotxa (gar-ROH-chah, named after a county), which did puncture the sail; its success was credited to its combination of firmness and flexibility. They did not attempt to splinter wood (or kill anyone), and it is possible that the Edam on Coe's ship was capable of wreaking the havoc reported.

BOX 11.5
BOVINE SOMATOTROPIN

All animals produce growth hormone in their pituitary glands, where it helps regulate metabolic processes. In calves, bovine somatotropin (BST), also known as growth hormone (BGH), helps with growth by building tissue. In lactating cows, it allows body fat to be used less for growth and more for the energy necessary for milk production. Small amounts of BGH are passed on to milk, where 90% of it is destroyed by pasteurization.

In the 1930s, injection of cows with BST was found to prevent mammary cell death, causing milk yield to increase. The use of BST was not cost-efficient then since it could only be obtained by extracting it from bovine pituitary glands. But by the 1990s it became economically feasible to produce BST by genetically engineering *E. coli*. This recombinant BST (abbreviated rBST or rBGH) boosts milk production by 10%–25%, though it increases the possibility of mastitis, an udder inflammation. It was approved by the U.S. Food and Drug Administration (FDA) in 1993 after determining that its use would be safe to humans. The FDA found that BST was not biologically active when consumed by humans, and that the milk from cows treated with rBST was no different than milk from untreated cows. Furthermore, the FDA ruled that milk and milk products cannot be labeled as "hormone-free" since all milk contains hormones, including tiny amounts of BST. It is impossible to tell whether milk contains BST, rBST, or both. To date, over 30 million American cows have received injections of rBST.

Nevertheless, only the United States, Mexico, most countries in Central and South America, and several other nations allow rBST. Many dairies, cheesemakers, and other manufacturers proudly state on their labels that milk from rBST cows is not used in their products. Why is there so much fuss about rBST? For one thing, consumers are wary about any changes to their milk—they have a strong emotional bond with baby's first food. Many people are concerned with the health of cows on rBST. Also, large operations are more likely to use rBST than family farms, giving them an economic advantage that many view as unfair.

BOX 12.5

FLAVOR PAIRING

> *"But I, when I undress me*
> *Each night upon my knees*
> *Will ask the Lord to bless me*
> *With apple-pie and cheese!"*
>
> —EUGENE FIELD, *The Poems of Eugene Field*, 1919

Most people do not enjoy eating two foods together if they have the same basic taste, because sensitivity to that taste is diminished and less desirable tastes become

BOX 12.5 (*continued*)

pronounced. Sweet foods and red wine both contain sugar; when consumed together, the tannins become more noticeable as one becomes desensitized to the sweetness.

On the other hand, people might like consuming two foods at the same meal if they have smaller amounts of flavorful common compounds. Wine, beer, and cheese contain acetaldehyde, phenylethanol, esters such as ethyl acetate, and some sulfur-containing compounds. Mozzarella, Parmesan, mushrooms, and tomatoes have compounds in common, including 4-methylpentanoic acid, which could help explain why pizza topped with mushrooms is popular. This is the basis for pairing some foods and wines with cheese. François Chartier, a chef and sommelier in Quebec, has explored the compounds that food and drink have in common. In his *Taste Buds and Molecules*, he lists a number of foods that should go with cheese because they contain compounds such as acetoin, linalool (described in the next chapter), and sotolon. Blue-veined cheeses and chocolate have over 70 compounds in common, and a few restaurants are preparing dishes featuring both.

But not everyone agrees with this idea. Some other compounds amplify or reduce flavors and may account for perceived pairing of flavors. For example, glutamic acid, a noted flavor-enhancer, is also found in the pizza components listed above, which may be the reason people like to consume them in one dish. Commenting on flavor pairing, Professor Hildegarde Heymann of the University of California–Davis told me "I personally do not quite buy it. I think ideal pairings have a great deal of situational effects that are not very dependent (or large) in terms of actual sensory effects." She and graduate student Berenice Madrigal-Galan used a trained panel to taste eight red wines (two each of Cabernet Sauvignon, Merlot, Pinot Noir, and Syrah) and eight cheeses (Gorgonzola, Stilton, Emmental, Gruyère, two Cheddars, Mozzarella, and Teleme) to see if wine flavor was affected by cheese, and vice-versa. They showed that, in general, each individual cheese had the same effect on all eight wines, finding that most of the wine aromas and flavors were suppressed. They theorized that binding of casein with volatile wine components prevented some of the aroma from being detected. The formation of a coating of milkfat in the mouth may also have prevented volatilization while producing a physical barrier to aroma compounds. Sourness in the wines was suppressed because the salt in the cheese counteracted the acid in the wine. The butter aroma in wine, originating in the diacetyl, was the only attribute that was enhanced. The authors concluded that any preferred cheese could be enjoyed with any preferred red wine.

Some scientists feel that flavor pairing is a fad, that we have a shortage of data, and that we know too little about the workings of the brain in processing taste and aroma inputs from various receptors. Others feel that the concept makes sense and that a real effect exists, even if it can't be explained yet. At some point, we will find out which side is right.

BOX 13.1
BABY CHEESE

Sbrinz (from Brienz, a town) and Saanen (another town) are very hard cheeses from the Swiss Alps. Sbrinz is similar to (and may be inspiration for) Parmesan, and is purported to be the oldest European cheese. Some wheels of Saanen are literally the oldest cheeses in Europe—they are often made to commemorate a birth, and pieces are eaten on special occasions throughout the person's life. If he or she has a notable career, small pieces of the cheese may be consumed for decades after his or her death. Sbrinz and Saanen are full-fat cow's milk cheeses cooked at 130°. Sbrinz weighs 80 pounds, Saanen weighs 12–25 pounds, and both are aged at least two years.

In England there was a superstition, lasting through the nineteenth century, in which a husband would have a wheel of hard cheese made to insure his wife's good delivery. Called a "groaning cheese," alluding to her complaints during childbirth, it was eaten from the center outward, starting when the baby arrived and continuing until the cheese became ring-shaped. The newborn was passed through the middle of it on the day of the christening. Small pieces of the first cut of the cheese were placed in the midwife's smock to cause young women to dream of their lovers, or placed under the pillows of young people for the same reason.

BOX 13.2
SUFFOLK CHEESE

"And, like the oaken shelf whereon 'tis laid,
Mocks the weak efforts of the bending blade;
Or in the hog-trough rests in perfect spite,
Too big to swallow and too hard to bite."
—ROBERT BLOOMFIELD, "The Farmer's Boy: A Rural Poem," 1800

Bloomfield was writing about Suffolk cheese, which was made in that English county. It was manufactured from full-fat milk until 1650, when cattle disease reduced milk production. To recoup their losses, dairies began to skim off the fat from their milk to make butter, which sold at a premium in London, and made Suffolk cheese from skim milk. Many consumers griped about the hardness of the cheese: a 1661 diary entry by Samuel Pepys mentioned that he and his wife were "vexed" at the servants for grumbling about having to eat Suffolk cheese. But it was cheaper than cheeses with normal fat contents, and in 1677, Pepys himself drew up standards requiring Royal Navy sailors to receive 4 ounces of Suffolk cheese or 2.7 ounces of Cheddar three days a week. The basic cheese ration remained in effect for another 170 years, but Suffolk was replaced in

(*continued*)

BOX 13.2 (*continued*)

1758 when cheesemakers began to reduce the aging time in response to heavier demand during the Seven Years' War, resulting in even more complaints. By then, Suffolk was known as a very hard cheese that became even harder with age (sailors were said to have carved it into buttons), but the manufacturing shortcuts taken could cause it to be too soft, which led to spoilage and infestation with long red worms.

Stories about the hardness of Suffolk abounded. In the 1720s, Daniel Defoe referred to Suffolk County as being "famous for the best butter, and perhaps the worst cheese, in England." Bloomfield referred to it as "the well-known butt to many a flinty joke." In 1885, Charles Dickens noted the saying that "hunger will break through stone walls or anything but Suffolk cheese" and related the tale of Suffolk bound for India packed in sheet tin—the rats gnawed through the tin but could not eat the cheese. Suffolk cheese became scarce by the 1950s, though new versions are now being made artisanally.

BOX 14.2
ON THE OTHER HAND . . .

> *"We recommend deleting milk and dairy products from your grocery list or taking them in extremely small quantities. You can make up the minerals by taking bone meal and the B vitamins with brewer's yeast."*
>
> —J. I. RODALE, *The Complete Book of Food and Nutrition*, 1961

You wouldn't be reading this book if you ate bone meal and brewer's yeast instead of cheese and other dairy products. Rodale was concerned about antibiotics finding their way into milk, but sick cows are now taken out of the milk supply. Farmers can tell if a cow is ailing by checking the milk for the number of somatic cells, the white blood cells that indicate that a cow is fighting an infection. Analyses are always run on every truckload of milk, and if trace amounts of antibiotics are detected, which happens a few times a year across the United States, that milk is then dumped. Tests for six common antibiotics such as penicillin take just minutes, and the FDA is looking for rapid techniques for other antibiotics (the current tests take a week for results to appear and the milk would be in stores by then). The institute Rodale founded is now working with our laboratory on the properties of organic milk from pasture-fed cows.

Some people just don't like cheese. The conversion of milk by microorganisms into a solid product is accompanied by the liberation of strong-smelling compounds. Some of these compounds are also generated when microbes spoil food, work in the digestive system, consume dead animals, and do other things that microbes do. To avoid food

BOX 14.2 (*continued*)

poisoning, people are taught to shun decay and some are sensitive to the aromas surrounding it, causing them to shy away from safe products created by controlled spoilage.

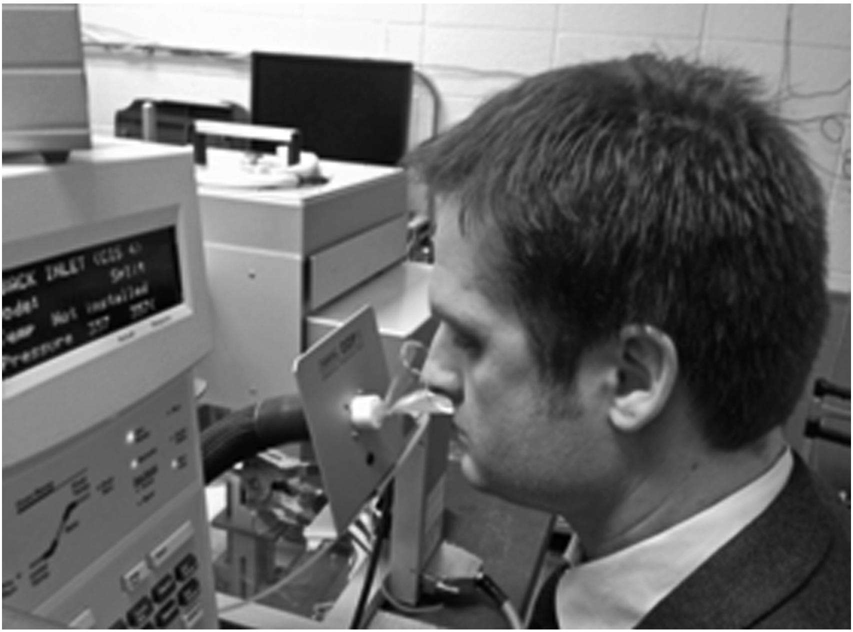
Others do not eat cheese by choice. Vegetarians do not eat meat, fish, or poultry. Lacto-vegetarians eat dairy products but not eggs, ovo-vegetarians eat eggs but not dairy products, ovo-lacto-vegetarians eat both, and vegans are people who won't eat any product of animal origin. Some vegetarians will not consume cheese made with animal rennet, considering it to be a meat product. Microbial or vegetable rennets are acceptable to them, and some artisanal and industrial cheesemakers market their products for this group of vegetarians.

Finally, some people restrict their cheese consumption because of possible adverse health effects. We explained in this chapter that these worries may be overblown, but in any case it is always best to consume food in moderation. Even if a food is good for you, too much of it isn't. And foods that are not good for you are tolerable in small amounts. Remember that cheese consumption continues to climb—as does life expectancy.

BOX 15.1

IT GOES UP YOUR NOSE

Flavor compounds are determined by gas chromatography (GC). The flame mentioned above in connection with FAMEs is a type of *detector*, a sensor that is responsive to the compounds being examined. Another type of detector used with GC is the mass spectrometer (MS), which bombards the compound with electrons coming from a filament (comparable to the one inside an incandescent light bulb). The electrons cause the molecule to fragment in a predictable way, and the instrument's software suggests which compounds may correspond to the fragmentation pattern. The scientist decides the most likely one, does the same for the other patterns, and thus compiles a list of what compounds are in the sample and how much of each is present. Whereas GC is capable of looking at one class of compound at a time, such as fatty acids, GC-MS can examine



Prof. Devin Peterson of the University of Minnesota detecting cheese aromas using gas chromatography-olfactometry.

Source: Courtesy of Devin Peterson.

BOX 15.1 (*continued*)

various classes. The technique is used in forensics and airport security, and NASA has launched several interplanetary probes with a GC-MS instrument inside.

Another GC detector is the human nose. In this technique, gas chromatography-olfactometry (GC-O), the gas that exits the GC is split, with half going into an MS unit and the other half traveling through a heated tube that is smelled by a scientist (in the photo below, it's Dr. Devin Peterson of the University of Minnesota). As each odiferous compound passes through, the scientist notes the aroma. One thus determines not only which odor-active compounds are present in a sample, but what they smell like in a cheese matrix. GC-O is valuable because it provide guidance to understanding what volatile compounds potentially contribute to the aroma of foods.

BOX 15.3
CHEESE CONTESTS

"One cheese differs from another, and the difference is in sweeps, and in landscapes, and in provinces, and in countrysides, and in climates, and in principalities, and in realms, and in the nature of things."

—HILAIRE BELLOC, *First and Last*, 1911

You can measure the differences in cheese for yourself or rely on experts to make a recommendation. Annual contests provide an opportunity for trained cheese judges to evaluate the products of various companies, score them, and determine winners. The Wisconsin Cheese Makers Association has some 2,300 entries grouped into 40 classes at their World Championship Cheese Contest, which is held in even-numbered years. Cheeses are broken out into different categories. The Cheddar class, for instance, includes mild (aged 0–3 months), medium (3–6 months), sharp (6 months–1 year); aged 1–2 years, aged 2 years or more; bandaged (ripened in a cloth wrapping) mild to medium, and bandaged sharp to aged. In 2010 they had 35 judges from 16 countries, including Nana Y. Farkye, a professor in the Dairy Science Department at California Polytechnic State University in San Luis Obispo (who also supplied much of the information below). Nana and the other judges employ a 100-point scoring system including flavor (45 points), body and texture (30), make up and appearance (15), color (5), and rind development (5). Working on the assumption that each cheese/entry is the best a company has to offer, the judges start with an initial score of 100 from which deductions are made for defects to give the final score. A perfect score of 100 is an exception, while scores less than 95 are unusual. Two judges independently score each cheese, and the final score for each entry is the average score of the two judges. The deductions for defects are on a one-tenth point basis: Very slight defect—detected under very critical examination, 0.10 to 0.50; Slight defect—detected upon critical examination, 0.50 to 1.50; Definite defect—detected easily, but not intense, 1.60 to 2.50; and Pronounced—detected easily and intense, 2.60 or greater. Because each judge is experienced, the pair working together may confer with each other initially at the beginning of judging each class to make sure they are seeing the same defects in each entry.

The American Cheese Society has around 100 categories and over 1,000 entries at their annual meeting. A technical judge (who looks at body, flavor, and texture) deducts points from 50, and an aesthetic judge (appearance, aroma, flavor, texture) adds points up to 50. A suggested score card for Cheddar by the American Dairy Science Association lists these flavor defects: bitter, feed (tastes of animal feed), fermented (vinegary), flat/low flavor, fruity, heated (reminiscent of spoiled milk), high acid, oxidized, rancid, sulfide, unclean (dirty aftertaste), whey taint, and yeasty. Their body and texture defects are corky (dry and hard), crumbly (falls apart), curdy (rubbery), gassy (eyes), mealy (grainy), open (spaces in the interior), pasty (sticky), short (flaky), and weak (soft). Appearance defects are not listed but may include mold, mottled, off-colors, and white specks. The specks would be the crystals and NaCl deposits mentioned in the "sound" section of Chapter 6.

BOX 15.4
GRADING CHEESE

USDA graders come into cheese plants or warehouses to give their unbiased opinions on the products. They examine the condition of the cheese container and compare the weight marked on it with the actual weight. Then they use a trier like the one shown in Chapter 3 to extract a cylindrical "plug" of cheese and examine it by sniffing, touching, and tasting. They also cut the cheese in half and examine the two cut surfaces. Any defects are noted, along with the descriptors "very slight," "slight," and "definite." The type and extent of defects are compared with the standards for that cheese variety, and a grade is then assigned. For Swiss-type cheese, the grades are A, B, and C; and for Cheddar, AA, A, B, and C. Barrels containing at least 100 pounds of American cheese are assigned U.S. Extra Grade, U.S. Standard Grade, or U.S. Commercial Grade. Any cheese scoring below the requirements would be listed as "No final U.S. grade assigned." To quote from one standard:

> The determination of U.S. grades of Swiss cheese shall be on the basis of rating the following quality factors: (1) Flavor, (2) Body, (3) Eyes and texture, (4) Finish and appearance, and (5) Color . . . in a randomly selected sample representing a vat of cheese . . . The final U.S. grade shall be established on the basis of the lowest rating of any one of the quality factors.

The eye and texture defects for Swiss-type cheeses were described in Box 12.2, and we'll use that information to look at the standard for Grade B Swiss and Emmental cheese:

> The cheese shall possess well-developed round or slightly oval-shaped eyes. The majority of the eyes shall be 3/8 to 13/16 inch in diameter. The cheese may possess the following eye characteristics to a very slight degree: dead eyes and nesty; and the following to a slight degree: dull, frogmouth, one sided, overset, rough, shell, underset, and uneven. The cheese may possess the following texture characteristics to a slight degree: checks, picks and streuble.

Grade A cheeses are allowed very slight dull, rough, shell, checks, picks and streuble, and none of the other defects. Grade C cheeses would have slight or definite levels of any or all of the defects in Box 12.2.

BOX 15.5
THE CHEESE CAPER

"We sat through two and a half hours of a fantastic murder mystery that had more holes in it than a piece of Swiss cheese."
—MICKEY SPILLANE, *I, the Jury*, 1947

Although most cheese scientists are not hardboiled detectives like Spillane's Mike Hammer, they are sometimes involved in legal matters. As we will see in Chapter 17, the labeling of a number of cheese varieties is regulated, and science is used to track down possible violators. In the late 1980s, the USDA's Agricultural Marketing Service (AMS), which purchases cheese and other commodities for the National School Lunch Program, came to us with a problem. A plant from which AMS purchased Mozzarella was found by inspectors to contain bags of calcium caseinate powder, which could have been added to the milk to increase the yield of cheese inexpensively. The regulations prohibit the use of milk powder in making genuine Mozzarella; if added, the cheese would have to be labeled as imitation. AMS suspected that the plant was selling imitation cheese to them but had no way of proving it. We found that the composition of their cheese was no different from authentic Mozzarella's, and the pattern of protein breakdown was also the same. But then I looked at the melting characteristics of their product and found something wrong. I used a differential scanning calorimeter (DSC), which measures the heat taken in or given off (the "calorimeter" part) by a sample in a tiny pan as it is heated or cooled ("scanning") and compared to an empty pan ("differential"). When the cheese was removed from the refrigerator, and heated immediately in the DSC, the amount of fat that melted at 60°–64° was too low. We made some Mozzarella containing 1% and 2% calcium caseinate and saw that the amount of fat melting in that temperature range decreased. The caseinate apparently acted as an emulsifier and prevented some of the fat from solidifying in the refrigerator, meaning that it would already be liquid when the cheese was heated, producing a smaller DSC signal. We then looked at microstructure with an SEM and saw that the fat globules in genuine Mozzarella were uniformly dispersed, but were often coalesced into large globules in the company's cheese and in the 1% and 2% calcium caseinate cheeses. With this information, we concluded that the company was making imitation Mozzarella and passing it off as genuine. The company, which had been taken to court, changed their plea from not guilty to guilty. They were convicted, fined $515,000 for defrauding the U.S. Government, and went out of business.

Scientists use other advanced techniques to determine if a cheese is really from the place identified on the label. They will see if the microorganisms match those in the place of origin and do the same with ratios of the chemical elements present. If they observe bacteria that are not found in the starter culture or NSLAB of a variety made in a particular area, then the cheese was probably made elsewhere. Similarly, the geology of a region will lead to proportions of certain elements being present in the feed and eventually the cheese.

BOX 15.5 (*continued*)

A major issue with some varieties is the substitution of goat, sheep, or water buffalo milk by cow milk, which is less expensive. Electrophoresis and chromatography are often used to confirm authenticity. ELISA (enzyme-linked immunosorbent assay) is a test in which enzymes and antibodies or antigens are used in a reaction to produce a color change. Specific proteins found in the milk of various species are identified in this manner. ELISA is most often used to detect virus antibodies, some drugs, and food allergens. In another identification technique, PCR (polymerase chain reaction), a section of DNA is separated into its two strands, an enzyme (DNA polymerase) is used to synthesize two-stranded DNA from each strand, and the process is repeated until many copies of the original are formed. PCR is now a mainstay of forensics and disease diagnosis. ELISA and PCR are not routine procedures, but manufacturers may resort to them if they are losing business to competitors who are adulterating their products.

BOX 15.6
IMPERIAL RUSSIA AND CHEESE SCIENCE

Two noted scientists who lived in the Russian Empire were involved in cheese and cheese cultures.

Dmitri Mendeleev (1834–1907) was a chemist who developed the periodic table of the elements and had element 101, Mendelevium, named after him in 1955. He was also a consultant on agricultural matters, including artisanal cheese production, which he thought could be a model for organizing industry. Mendeleev was a member of Russia's Free Economic Society for the Encouragement of Agriculture and Husbandry, a learned society independent of the government that operated from 1765 to 1919. (Luminaries such as Leo Tolstoy were also members.) Mendeleev was supposed to inspect cheesemaking cooperatives for the Society on March 1–12, 1869, but had to delay the trip by a day because his final form of the periodic table was completed and sent to printer on March 1. A colleague presented the periodic table paper to the Russian Chemical Society later that month.

Ilya (also translated as Élie) Metchnikoff (1845–1916) shared the 1908 Nobel Prize in Physiology or Medicine for his research on the immune system. In his later work he incorrectly theorized that aging is caused by slow poisoning by toxins that pathogens produce in the digestive system, and that resistance is weakened as these bacteria proliferate. He concluded that lactic acid bacteria such as those we first mentioned in Chapter 2 would counteract these effects and prolong life. Metchnikoff singled out the thermophile *Lactobacillus bulgaricus* (now called *Lactobacillus delbrueckii* subspecies *bulgaricus*) as having the ability to establish itself in the intestine (it doesn't) and to prevent pathogens there from multiplying (it can't). Others then found that *Lactobacillus acidophilus*, the yogurt culture we first met in Box 4.1, is capable of colonizing the

BOX 15.6 (*continued*)

gastrointestinal tract and exerting a healthful physiological effect. Japanese scientist Minoru Shirota found that a particular strain of another culture used for cheese, *Lactobacillus casei*, also survives in the gut and assists in good intestinal health. In 1935 Shirota began to produce Yakult, a fermented skim milk drink that is quite popular in his native Japan and other places. This product helped accelerate interest in probiotics, live microorganisms that confer a health benefit when adequate amounts are consumed. Some probiotic cheeses have been developed, but the most popular probiotic product that eventually resulted from Metchnikoff's work is commercial yogurt.

BOX 15.7
REPORTING CHEESE RESEARCH

When academic, government, and some industrial scientists complete an aspect of their research, they try to publish a paper about it in a scientific journal. Papers' elements are usually arranged in this order: an abstract, which summarizes the work; an introduction providing background information on the problem being examined, why they are examining it, and the research that has been done previously; materials and methods, describing how the work was performed, with enough detail so that others can repeat it; results and discussion, where the findings are presented and explained along with tables, graphs, and pictures; a conclusion tying everything together; acknowledgements of people and organizations who helped; and a list of articles that the authors cited. Most papers are submitted and published online, which greatly reduces costs. When a paper is received, the journal's editor-in-chief sends it out to at least two scientists in that field who offer suggestions to improve it (though they may reject it altogether). This peer-review process is meant to insure that the quality of the work is sound. The editor has the final decision on whether the paper is good enough to print. A variety of scientific journals publish papers about cheese science, including:

Journal of Agricultural and Food Chemistry
Journal of Food Science
Journal of the Science of Food and Agriculture
Food Chemistry
Food Research International
LWT—Food Science and Technology (the original title was *Lebensmittel-Wissenschaft und Technologie*)
Advances in Food and Nutrition Research
Critical Reviews in Food Science and Nutrition
Trends in Food Science and Technology

Some journals focus on dairy foods. These include:

(*continued*)

BOX 15.7 (*continued*)

International Dairy Journal
International Journal of Dairy Technology
Journal of Dairy Research
Journal of Dairy Science
Dairy Science and Technology (formerly *Le Lait*)

Scientists may opt to publish in other specialized journals that sometimes have articles about cheese, such as *Journal of Food Engineering, Journal of Food Protection, Journal of Texture Studies*, and *Small Ruminant Research*.

Cheesemakers and cheese scientists also read monthly trade journals, such as *Food Product Design* and *Prepared Foods*. Two weekly trade newspapers are also published, *Cheese Reporter* and *Cheese Market News*.

BOX 16.2
U.S. CHEESE IMPORTS AND EXPORTS

As mentioned in Box 6.2, the United States exported nearly half a billion pounds of cheese and imported 313 million pounds in 2011. Table B16.2-1 lists the leading destinations for American-made cheese in that year.

Half of these countries are in eastern Asia, which shows that their attitudes toward dairy foods are changing. Traditionally, residents of those places did not consume milk, butter, or cheese to a great extent since it was not part of their culture (though dairy products were introduced to Japan when that country modernized in the latter part of the nineteenth century). With increasing globalization, Chinese, Koreans, and others are being exposed to these products, trying them, and liking them. In fact, part of our laboratory's research on Queso Fresco was performed by a visiting scientist from Harbin, China.

The USDA's Foreign Agricultural Service classifies imports by type and country. The leading countries that exported cheese to the United States in the first half of 2012 are listed in Table B16.2-2:

TABLE B16.2-1

Leading exporters of cheese to the U.S.

Type	*Countries*
Blue mold	Denmark, Germany, France
Cheddar	United Kingdom, New Zealand, Australia, Ireland
Edam and Gouda	Netherlands
Gruyère	Netherlands, Germany, Switzerland
Italian type	Argentina, Italy
Swiss and Emmentaler	Finland, Norway, France, Switzerland
All others	France, Denmark, Ireland, Netherlands, Italy

TABLE B16.2-2

Leading importers of American-made cheese

Country	Millions of pounds
Mexico	106.5
South Korea	77.4
Japan	50.5
Canada	24.6
Saudi Arabia	24.3
Australia & Oceania	23.8
Egypt	16.2
China & Hong Kong	18.9

BOX 16.3 (*continued*)

Country	Consumption (pounds per capita)
Germany	49.7
Switzerland	47.1
Netherlands	46.2
Italy	46.0
Finland	45.5
Sweden	41.6
Austria	38.3
Czech Republic	36.7
Norway	33.7
Hungary	24.2
United Kingdom	24.0
Poland	23.8
Slovakia	20.9
Spain	18.0
Russia	12.3
ELSEWHERE	
Turkey	42.7
Israel	36.1
Australia	26.4
New Zealand	13.2
Japan	3.7

BOX 16.4
DO YOU WANT FLIES WITH THAT?

> *"The whole round sea was one huge cheese, and those sharks the maggots in it."*
> —HERMAN MELVILLE, *Moby Dick*, 1851

"Maggot" is the common name for fly larva, including fly species that inhabit cheese. The most common fly associated with cheese is *Piophila casei*, also known as the "cheese skipper," so named because the larvae can propel themselves through the air. They feed

BOX 16.4 (*continued*)

on decomposing protein, which is why they are also found on dead animals, including humans. *Piophila casei* pupae (the stage between larvae and adult) were found on a packet of organs in the abdomen of an Egyptian mummy dating to approximately 170 BC. Their size and age are used to date corpses, but they prefer stored foods, especially cheese. Maggots, flies, and mites were commonly found on cheese until well into the twentieth century, but modern hygienic practices and storage systems have eliminated this annoyance.

One cheese variety deliberately includes flies and is illegal to sell, though it can be made for home consumption. Casu Marzu ("rotten cheese") is a sheep's milk cheese made in Sardinia and containing live larvae of *Piophila casei*. Pecorino is left in the open air with part of the rind removed to allow cheese skippers to lay eggs. When they hatch, the larvae eat their way into the cheese, breaking down the fat and protein to the point where some of the structure liquefies. The cheese is considered safe to eat as long as the maggots are alive. Cheese skippers are able to jump a few inches, so consumers are advised to protect their eyes. People who do not wish to eat live maggots will place Casu Marzu inside a paper bag and seal it. The maggots will bang around in the bag until they have suffocated, and the cheese is then consumed. *Guinness World Records 2009* listed it as the most dangerous cheese to human health. The Italian government considers it to be a traditional food that has been continuously produced for more than 25 years, making it exempt from some of their safety rules. This type of product will never fly in other countries, where regulations prohibit such a thing.

Cheese skipper.

BOX 16.5
MITES

"*The cheese-mites asked how the cheese got there,*
And warmly debated the matter;
The Orthodox said that it came from the air,
And the Heretics said from the platter.
They argued it long and they argued it strong,
And I hear they are arguing now;
But of all the choice spirits who lived in the cheese,
Not one of them thought of a cow."
—ARTHUR CONAN DOYLE, *Songs of Action*, 1898

Cheese mites include *Acarus siro* and *Tyrolichus casei*, and used to be considered inseparable from cheese. The 1811 dictionary cited in Box 1.2 lists "mite" as slang for cheesemonger. The very first science documentary movie was *Cheese Mites*, filmed through a microscope and shown in a theater in London's Leicester Square in 1903. The movie, which lasts less than a minute (and may be viewed online), showed mites of various sizes crawling around a piece of cheese. For some time thereafter, inexpensive microscopes often included packets of mites for the customers' viewing pleasure.

In the past, cheese mites were often consumed along with the cheese. In Thomas Reade's classic 1861 novel *The Cloister and the Hearth*, which was set in the fifteenth century, the protagonist was appalled to be served a cheese thoroughly consumed by mites, though his dining companions thought nothing of it ("These nauseous reptiles have made away with every bit of it." "Well, it is not gone far. By eating of the mites we eat the cheese to boot"). Even today, cheese mites are deliberately introduced into a couple of cheese varieties to produce a characteristic nutty and fruity flavor. When the cheese has aged sufficiently, it is covered with a powder of living and dead mites along with their feces and molted skins. Milbenkäse ("mite cheese") hails from Würchwitz, Germany, where a cheese mite statue stands. Caraway-flavored Quark is placed in a box containing *Tyrolichus casei*, and the product is consumed after aging. The rind is reddish brown after three months and black after a year. Mimolette Vieille (from the French *molle*, "soft," referring to the crust of the immature cheese, and *vielle*, "aged") originated in Lille, France as a version of Edam. It is shaped like a sphere and colored with annatto. *Acarus siro* are sprinkled on the surface, tuning the rind gray and crumbly after a year, making this variety resemble a rusty cannonball. If uncontrolled, *Acarus siro* can consume up to a quarter of a piece of cheese, leaving a powder nearly an inch high.