THE SCIENCE OF

CHEESE

MICHAEL TUNICK

THE SCIENCE OF CHEESE

This page intentionally left blank

The Science of Cheese

Michael H. Tunick

OXFORD
UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research,
scholarship, and education by publishing worldwide.

Oxford New York
Auckland Cape Town Dar es Salaam Hong Kong Karachi
Kuala Lumpur Madrid Melbourne Mexico City Nairobi
New Delhi Shanghai Taipei Toronto

With offices in
Argentina Austria Brazil Chile Czech Republic France Greece
Guatemala Hungary Italy Japan Poland Portugal Singapore
South Korea Switzerland Thailand Turkey Ukraine Vietnam

Oxford is a registered trade mark of Oxford University Press
in the UK and certain other countries.

Published in the United States of America by
Oxford University Press
198 Madison Avenue, New York, N.Y. 10016

© Oxford University Press 2014

All rights reserved. No part of this publication may be reproduced,
stored in a retrieval system, or transmitted, in any form or by any means, without the
prior permission in writing of Oxford University Press, or as expressly permitted by law,
by license, or under terms agreed with the appropriate reproduction rights organization.
Inquiries concerning reproduction outside the scope of the above should be sent
to the Rights Department, Oxford University Press, at the address above.

You must not circulate this work in any other form
and you must impose this same condition on any acquirer.

Library of Congress Cataloging-in-Publication Data
Tunick, Michael.
The science of cheese / Michael H. Tunick.
pages cm.
Includes bibliographical references and index.
ISBN 978-0-19-992230-7 (alk. paper)
1. Cheesemaking. I. Title.
SF271.T86 2014
637′.3—dc23 2013010729

9 8 7 6 5 4 3 2 1

Printed in the United States of America
on acid-free paper

For Gail, Dan, and Susan

This page intentionally left blank

Contents

Preface ix
Acknowledgments xiii
U.S. and Metric Units xv
Periodic Table of the Cheeses xix

1. *In the Beginning: Milk* 3

2. *Curds and Whey: Cheesemaking* 21

3. *You're Not Getting Older, You're Getting Better: Aging Cheese* 49

4. *Fresh Soft Cheeses, Acids, and Safety* 58

5. *Whey and Pickled Cheeses, Amino and Fatty Acids, and Salt* 68

6. *Stretched Curd Cheeses, Alcohols, and Melting* 82

7. *Surface Mold Cheeses, Sulfur Compounds, and the Senses* 92

8. *Smear-Ripened Cheeses, Esters, and Aroma* 99

9. *Interior Mold Cheeses, Ketones, and Microbial Strains* 107

10. *Cheddared Cheeses, Aldehydes, and Texture* 117

11. Washed Curd Cheeses, Lactones, Feed, and Species 128

12. Cheeses with Eyes, Furans, Hydrocarbons, and Food Pairing 139

13. Very Hard Cheeses, Terpenes, and Terroir 150

14. Process Cheeses and Nutrition 159

15. Analysis and Flavor Comparisons 174

16. Laws, Regulations, and Appellations 199

17. Do Try This at Home 229

18. The Cheese Stands Alone 239

GLOSSARY 243
REFERENCES 247
INDEX 273

Preface

> Cheese. The adult form of milk. Hard and soft; new, mature, and overripe.
> Graced with a spectrum of smells from wispiness to shocking assault upon the nostrils.
> —RICHARD CONDON, *A Talent for Loving*, 1961

PEOPLE HAVE BEEN enamored with cheese for a long time. The intricate combinations of appearance, aroma, flavor, and texture have inspired writers to refer to cheese as "milk's leap toward immortality" (Clifton Fadiman), "the soul of the soil" (Pierre Androuët), and "the wine of foods" (Vivienne Marquis and Patricia Haskell). Cheese has much in common with wine and beer: they result from fermentation by microorganisms, they are "value-added" products (processing greatly increases the value of milk, grain, and grapes), and they reflect the local climate and terrain. Cheese may be kept for months, and traditionally provided a source of protein, vitamins, and minerals during the winter when other food was scarce. Cheese is nutritious and delicious, and can be appealing or appalling. There has been a great deal of research on this complicated food—over 20,000 scientific papers about some aspect of cheese have been published over the past ten years alone. Some authors have distilled this information down to the basics for the general public, and others have written works that most people without a scientific background are unable to understand. I've tried to take the middle ground, by writing about the science without getting too technical. Like many books on this subject, we will cover milk (Chapter 1),

the fundamentals of making cheese (Chapter 2), aging cheese (Chapter 3), and the different classes of cheese (chapters 4–13). But we will also cover the chemical compounds involved and how the flavors arise as we talk about cheese classes, and we will detail nutrition (Chapter 14), how cheese is analyzed (Chapter 15), rules, regulations, and specially designated cheeses (Chapter 16), things you can do at home (Chapter 17), and other topics besides.

This book is a product of the accomplishments of two organizations, the American Chemical Society (ACS) and the Agricultural Research Service (ARS). ACS has over 160,000 members worldwide who conduct research in chemistry, teach it, or write about it. Scientific societies like ACS promote knowledge by holding meetings where scientists present results of their research, by publishing journals and books based on these results, and by providing online information, including webinars. ACS began offering webinars to its members in 2010 and started a series called "Chemistry of Food" the following year. The first presentation was given by Charles Bamforth on the chemistry of beer, and I had the third talk, titled "The Chemistry of Cheese and Why We Love It." Oxford University Press had already published three editions of Charles's book *Beer: Tap into the Art and Science of Brewing*, and they were looking for someone to write a general-interest book on cheese chemistry. They viewed my webinar, invited me, and the result is in front of you.

ACS has over 30 technical divisions dealing with various areas of chemistry. One of these, the Division of Agricultural and Food Chemistry (AGFD), has been an all-volunteer group since its formation in 1908. I was chair of AGFD in 2001 and am its secretary now. Most divisions including AGFD hold symposia at the two annual ACS meetings in March/April and August/September. Some of our recent symposia have covered such diverse topics as nanotechnology, tree nuts, bioactives, cereal grains, waste utilization, subtropical fruits, consumer safety, chocolate, allergens, Hispanic foods, flavors, and many more. ACS and AGFD are geared for professionals in the field, but they do have resources for the general public, available online at acs.org and agfd.sites.acs.org.

My employer is ARS, the primary research arm of the United States Department of Agriculture. ARS has nearly 100 facilities across the country, and one of the largest is the Eastern Regional Research Center in Wyndmoor, Pennsylvania, just outside of Philadelphia. The Center has six research units focused on aspects of agricultural research, including the Dairy and Functional Foods Research Unit, where I am. The Unit and its predecessors have conducted research on cheese and other dairy products since the late nineteenth century. Of our many advances over the years, the most visible to consumers is lactose-reduced milk, which will be discussed in Chapter 1. We also developed a reduced-fat Mozzarella that has been used in the National School Lunch Program since 1995. Nowadays, our work deals with cheese characterization

and safety; whey utilization; conversion of milk casein to edible films; development of bacterial cultures for cheesemaking and bioactive peptides and proteins; lowering the environmental and economic impacts of food processing; and development of products from plant cell-wall polysaccharides in fruit and vegetable processing residues. ARS also has online resources for people who may not be scientists but who are interested in topics related to food (www.ars.usda.gov). Our agency is committed to public outreach, and has been for a long time. In fact, a book titled *Varieties of Cheese: Descriptions and Analyses* was first published by USDA in 1908, renamed *Cheese Varieties and Descriptions* in 1953 (this edition is available at the National Agricultural Library website), and revised again in 1978.

Many other books describe cheese varieties, along with recipes and how to buy and serve cheese. But this book will describe the chemistry, biology, physics, nutrition, and even climatology involved in cheese. It is arranged so that the more technical topics are confined to boxes that you can skip (I won't be insulted, honestly). Along the way, we'll encounter some related topics that will add to the discussion.

About one-third of the milk produced in the United States each year goes toward cheesemaking, and on average each American consumes around 34 pounds of cheese annually. Here is the story of the science behind it.

This page intentionally left blank

Acknowledgments

> It's hard to focus the mind on praise, one thinks too much of the holes in the cheese, or the slice of cheese, of the emptiness that goes with all good.
>
> —Beginning of letter from William Carlos Williams to fellow poet Marianne Moore, 1944

ACTUALLY, IT IS easy to praise the people who helped with this book. Thanks to Peggy Tomasula and Sevim Erhan for allowing me to write the book in the first place. Thanks to my other coworkers for their help over the years, especially Diane Van Hekken, Edyth Malin, Harry Farrell, and two long-time colleagues who unfortunately passed away several years ago, Virginia Holsinger and Phillip Smith. Edyth, Harry, and Ellie Brown are responsible for the molecular models. Ray Kwoczak is the cheesemaker at our lab (one of his make sheets is shown in Box 2.1), and Susan Iandola, Moushumi Paul, Jim Shieh, and Brien Sullivan are also on the project—thanks to all of them and to Peter Cooke and Doug Soroka, who produced the electron microscopy images. At the American Chemical Society, Samuel Toba and John Christensen invited me to give the webinar that started me on the path to this book. At Oxford University Press, Assistant Editor Hallie Stebbins invited me to write the book, and Associate Editor Mary Calvert and Editor Jeremy Lewis deserve my gratitude for getting it into publishable form, along with senior production editor Natalie F. Johnson, editorial assistant Erik Hane, and copyeditor Gail Cooper.

Thanks also to Sara Risch of Science by Design for advice on packaging, Linda Ettinger Lieberman at Moskowitz Jacobs, Inc., for checking the rules developing experimentation section of Chapter 14 and Hildegarde Heymann at University of California–Davis for information and opinions on complementary compounds. Thanks to Phil Wolff of the USDA's Dairy Grading Branch for checking the section on grading, to Nana Y. Farkye of California Polytechnic–San Luis Obispo for providing information on the World Championship Cheese Contest, and to Devin Peterson of the University of Minnesota for the information on gas chromatography-olfactometry and the photo. Special thanks to Paul McSweeney at University College Cork for reviewing the manuscript.

Thanks to Jim Victor and Mike Geno for allowing me to use pictures of their art work, and to Lois Tendler, Robert Sandell, and Karen Sandell-Stern for the milk bottle caps. Thanks also to my colleagues with the Division of Agricultural and Food Chemistry and my family for tolerating me. I have tried very hard to be as accurate as possible in this book; any errors are my fault. I also apologize if your favorite cheese isn't mentioned, but with thousands of varieties in the world, it is impossible to get to them all.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

U.S. and Metric Units

As different as chalk and cheese.
—British expression referring to two things outwardly alike but not the same

U.S. CUSTOMARY UNITS (degrees Fahrenheit, inches, pounds) are used in this book since Americans are more familiar with those than with the metric system. The conversions to degrees Celsius, millimeters, grams, and milliliters follow.

Temperatures

The temperatures given in this book are in degrees Fahrenheit. The equivalents in degrees Celsius, rounded off to whole numbers, are given in Table 0.1.

Length

A micrometer is a millionth of a meter, or a thousandth of a millimeter. An inch is equivalent to 25.4 mm. Table 0.2 shows some conversions from inches to millimeters.

TABLE 0.1

Conversions between Fahrenheit and Celsius

°F	°C	°F	°C	°F	°C
32	0	76	24	120	49
34	1	78	26	122	50
36	2	80	27	124	51
38	3	82	28	126	52
40	4	84	29	128	53
42	6	86	30	130	54
44	7	88	31	132	56
46	8	90	32	134	57
48	9	92	33	136	58
50	10	94	34	138	59
52	11	96	36	140	60
54	12	98	37	145	63
56	13	100	38	150	66
58	14	102	39	155	68
60	16	104	40	160	71
62	17	106	41	165	74
64	18	108	42	170	77
66	19	110	43	175	79
68	20	112	44	180	82
70	21	114	46	185	85
72	22	116	47	190	88
74	23	118	48	195	91

TABLE 0.2

Conversions between inches and millimeters

in	mm	in	mm	in	mm
1/8	3	¼	6	3/8	10
½	13	¾	19	1	25

Mass, Concentration, and Volume

A gram contains 1000 milligrams, and a kilogram contains 1000 grams. A kilogram is 2.2 pounds, so a 1000-pound cow would weigh 455 kilograms.

A concentration of one part per million (ppm) is equivalent to one gram in 1000 kilograms, or a drop of water in 13 gallons. A part per billion (ppb) is one drop in 13,000 gallons—the volume of a round swimming pool 18 feet in diameter and 7 feet deep.

A gram of water is equivalent to a milliliter of volume (also called a cubic centimeter, or cc for short). Thirty milliliters make up a fluid ounce.

This page intentionally left blank

PERIODIC TABLE OF THE CHEESES

This table includes the categories of cheese, major cheesemaking countries, and some noted varieties mentioned in this book. Each box contains the atomic number and symbol for one of the 114 chemical elements whose existence has been confirmed.

1 **H** Havarti																	2 **He** Herve
3 **Li** Limburger	4 **Be** Beaufort											5 **B** Brie	6 **C** Camembert	7 **N** Norwegian Jarlsberg	8 **O** Oscypek	9 **F** French cheese	10 **Ne** Neufchatel
11 **Na** Netherlands cheese	12 **Mg** Manchego											13 **Al** Afuega'l Pitu	14 **Si** Stirred curd cheese	15 **P** Process cheese	16 **S** Swiss type cheese	17 **Cl** Cantal	18 **Ar** Asiago Pressado
19 **K** Kefalotyri	20 **Ca** Caerphilly	21 **Sc** Stretched curd cheese	22 **Ti** Tiroler Almkäse	23 **V** Very hard cheese	24 **Cr** Crottin de Chavignol	25 **Mn** Mahón-Menorca	26 **Fe** Feta	27 **Co** Cottage	28 **Ni** Natural rind cheese	29 **Cu** Casciotta d'Urbino	30 **Zn** Ziegenkäse	31 **Ga** German cheese	32 **Ge** Greek cheese	33 **As** Asadero	34 **Se** Selles-sur-Cher	35 **Br** Brick	36 **Kr** Kasseri
37 **Rb** Reblochon de Savoie	38 **Sr** Surface mold cheese	39 **Y** Yarg Cornish	40 **Zr** Zamorano	41 **Nb** Naboulsi	42 **Mo** Mozzarella	43 **Tc** Torta del Cesar	44 **Ru** Rocamadour	45 **Rh** Raschera	46 **Pd** Picodon	47 **Ag** Allgäuer Bergkäse	48 **Cd** Cheddar	49 **In** Interior mold cheese	50 **Sn** Spanish cheese	51 **Sb** Sbrinz	52 **Te** Tête de Moine	53 **I** Italian cheese	54 **Xe** Xigalo Siteias
55 **Cs** Cabrales	56 **Ba** Batzios	*	72 **Hf** Humboldt Fog	73 **Ta** Taleggio	74 **W** Whey cheese	75 **Re** Red Leicester	76 **Os** Ossau-Iraty	77 **Ir** Ibores	78 **Pt** Pont-l'Évèque	79 **Au** Austrian cheese	80 **Hg** Homogenized milk cheese	81 **Tl** Tilsit	82 **Pb** Pickled/ brined cheese	83 **Bi** Bitto	84 **Po** Portuguese cheese	85 **At** Anevato	86 **Rn** Romano
87 **Fr** Fresh cheese	88 **Ra** Ricotta	**	104 **Rf** Roquefort	105 **Db** Daniblu	106 **Sg** Spressa delle Guidicarie	107 **Bh** Berner Hobelkäse	108 **Hs** Hushåollsost	109 **Mt** Maytag Blue	110 **Ds** Dorset Blue	111 **Rg** Ragusano	112 **Cn** Chevrotin		114 **Fl** Formaella Arachovas Parnassou		116 **Lv** Livarot		

*	57 **La** Langres	58 **Ce** Cebriero	59 **Pr** Provolone	60 **Nd** Noord Hollandse Edammer	61 **Pm** Parmigiano Reggiano	62 **Sm** Smear-ripened cheese	63 **Eu** Époisses de Bourgogne	64 **Gd** Gouda	65 **Tb** Tiroler Bergkäse	66 **Dy** Derby	67 **Ho** Halloumi	68 **Er** Esrom	69 **Tm** Tomme de Savoie	70 **Yb** Yorkshire Blue	71 **Lu** Laguiole
**	89 **Ac** Abondance	90 **Th** Tronchón	91 **Pa** Picodon l'Ardèche	92 **U** U.S. cheese	93 **Np** Non-pasteurized milk cheese	94 **Pu** Pouligny-Saint-Pierre	95 **Am** Allgäuer Emmentaler	96 **Cm** Casu Marzu	97 **Bk** Berner Alpkäse	98 **Cf** Cheese food	99 **Es** English style cheese	100 **Fm** Fourme d'Ambert	101 **Md** Mont d'Or	102 **No** Noord Hollandse Gouda	103 **Lr** Ladotyri Mytilinis

THE SCIENCE OF CHEESE

This page intentionally left blank

Did you not pour me out like milk and curdle
me like cheese?
—Job speaking to God, Job 10:10

1

IN THE BEGINNING

Milk

ONE WARM DAY in the Fertile Crescent some 8,000 years ago, a traveler started off on a journey with some milk in a pouch. The milk may have come from a sheep, which was one of the first animals to be domesticated, and the pouch was simply a sheep's stomach. After a while, the traveler stopped to take a drink from the pouch and discovered that the milk had separated into a soft white solid and a yellowish liquid. He took a taste of the solid and found it had a bland but agreeable flavor.

This is the most-told story about the first production of cheese; we know for certain that it was made in Northern Europe in the sixth millennium BC after archeologists analyzed residues in ceramic sieves found in modern-day Poland. Cheesemaking served as a way to preserve milk while providing nourishment to lactose-intolerant people (see below). Soon, others found that the flavor grew more intense the more days the cheese sat around; different species of animal produced different tasting cheese; and adding salt preserved it longer. The reasons behind all this are rooted in chemistry. The milk coagulated into a solid (the *curd*) and a liquid (the *whey*) because of enzymes in the stomach lining, and bacteria in the milk acted on the curd during storage to generate flavorful compounds. It took until the nineteenth century for anyone to realize this, but that didn't stop people from creating and experimenting with cheese. Now, more than 2,000 varieties of cheese are made around in the world. Some of today's varieties have been around for a while: Gorgonzola was first noted

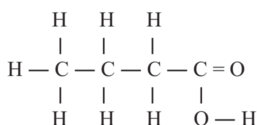
in AD 879, Roquefort in 1070, and Cheddar in 1500. More are being developed all the time, as cheesemakers apply trial and error and a combination of talent and luck.

The most important factors in cheesemaking are the composition of the milk, the development of acid as the curd forms, the amount of moisture in the curd, the way the curd is manipulated, and storage conditions. But before we continue, we should define some terms.

- **Moisture** is the amount of water in a food. Generally, the higher the moisture content is, the softer the cheese and the shorter the shelf life.
- **Fat** includes solid fats and liquid oils. A fat or oil molecule is in the form of a triglyceride, which consists of a "backbone" of glycerol bonded to three chains of *fatty acids*. If straightened out, the structure would resemble a capital E. The shorter fatty acid chains are volatile and contribute to aroma and flavor (one is depicted in Box 1.1 along with glycerol and a triglyceride). The fat in dairy products is often called *milkfat* or *butterfat*. Fats and oils are relatively stable in cheese, though they do degrade into flavor compounds. Cows produce less fat in summer than in winter. Feed also affects fat content in milk. Fat in milk is in the form of droplets, known as *globules*.
- **Protein** in cheese composes the network in which the fat globules and water are held. All proteins consist of *amino acids* linked together in a three-dimensional network, and typically almost all of the protein in cheese curd is *casein* (pronounced KAY-seen). Several other proteins are found in whey. Proteins will break apart with ripening, contributing to flavor and decreasing the hardness of the cheese. High heat or the addition of certain compounds will cause many proteins (though not casein) to unfold, or *denature*, resulting in a loss of biological activity. *Enzymes* are proteins that hook up with other molecules and speed up a chemical reaction. Milk has some 70 indigenous enzymes, and in most cases their role in cheese is unclear. We will see that non-indigenous enzymes added to the milk start the breakdown of casein and lactose.
- **Carbohydrate** in cheese is basically *lactose*, also known as *milk sugar*. Lactose will also break down to generate flavors. Milk is the only source of lactose found in nature.
- **Energy** refers to the caloric content of a food. A *food Calorie* (note the capital C) is the energy required to heat a kilogram of water by 1°C.
- **Minerals** include calcium and phosphorus in milk and the sodium chloride added to cheese.
- **Vitamins** are nutrients containing carbon, hydrogen, and oxygen that are required by the body and must be obtained from the diet. Vitamins A, D, E, and K are soluble in lipids, and the B vitamins and vitamin C are dissolved in water.

BOX 1.1
MOLECULAR STRUCTURES

Scientists find it easier to visualize molecules by drawing structures, using abbreviations for the chemical elements and lines for links between them. For instance, butanoic acid is a fatty acid found in cheese and rancid butter (the name comes from the Greek word for butter). Its structure fully written out looks like this:



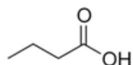
Each C represents a carbon atom, each H a hydrogen atom, and each O an atom of oxygen. A line, either horizontal or vertical, is a single chemical bond, in which two adjacent atoms share an electron. Each carbon atom may be linked, or bonded, to as many as four other atoms, which in this book may be hydrogen, oxygen, nitrogen, sulfur, or another carbon. The double line to the right represents a double bond, in which adjacent atoms share two electrons. An O is capable of having only two bonds, which in food may be one double bond with carbon or two single bonds. An H is limited to one single bond, which it may share with carbon, oxygen, nitrogen, or sulfur. When a number of C's are linked together in a series of bonds, we'll refer to the string as a *carbon chain*.

When you get more complicated molecules, all those C's and H's clutter up the structure. We can streamline the picture by using numbers:

$$CH_3CH_2CH_2COOH$$

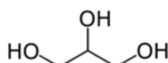
All we've done is remove the bonds, show the number of hydrogen atoms bonded to each carbon atom, and abbreviated the part with the oxygen atoms. Chemists know that COOH means that an O is double-bonded to a C, with an O-H also attached to the C. This COOH group tells us that the compound is an acid.

We can also depict the molecule without most of the H's, using a skeletal structure:



Here, we assume that the starting point on the left is a CH_3 and that every corner also corresponds to a C. The H's are only shown when their position is important or to avoid confusion. The H is shown with the last O here so we don't think something else is attached.

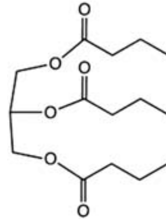
Glycerol, to which fatty acids are attached to form triglycerides, is a clear, syrupy substance often used in personal care products, where it is called "glycerin." Its skeletal structure looks like this:



(*continued*)

BOX 1.1 (*continued*)

A triglyceride consisting of three butanoic acid molecules therefore can be depicted as:



Molecules are not really shaped like any of these pictures. Instead, they bend themselves into the shapes requiring the least energy. Scientists use computer programs to find the most likely shapes, which they call *molecular models*. Some models of casein will be shown in Box 1.5.

Two more terms: for the purposes of this book, **artisanal** refers to cheese made primarily by hand in small batches from locally obtained milk using traditional methods. New varieties may be attempted, but the process is not fully mechanized. **Farmhouse** cheese is an artisanal cheese made on a farm from milk obtained from that farm's herd.

Mammals

Cows and other mammals have been used to make cheese since ancient times. Even the word *cheese* can be traced back a long way (Box 1.2). Almost 9.2 million milking cows are in the United States (Box 1.3), and six breeds of cow are responsible for 98 percent of the milk produced.

Table 1.1 lists the six cow breeds along with the amount and composition of the milk they produce. The last three columns are averages for Wisconsin cows.

Holsteins, also known as Holstein-Friesians, were developed in Holland and Germany more than 2,000 years ago. These are the familiar black and white animals that most people imagine when they think of cows. Holsteins are considered rugged and good feeders. They are the most efficient breed in generating large amounts of milk. Jerseys originated in the Channel Island of that name and are cream or light brown, sometimes with patches of white. They are sensitive and are finicky eaters, and are noted for producing more fat and protein than other breeds. Research in our laboratory showed that Jersey milk is more suitable for cheesemaking than the milk of the other five breeds; the more milk protein that is casein, the better the yield of cheese, and Jersey milk is the only one with over 83 percent of protein as casein. You can

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.

TABLE B1.3

States with 1,000+ dairy farms

State	Dairy farms	Dairy cows
Wisconsin	12,100	1,265,000
Pennsylvania	7,240	538,000
New York	5,450	610,000
Minnesota	4,325	465,000
Ohio	3,170	269,000
Michigan	2,160	369,000
California	1,675	1,778,000
Iowa	1,670	201,000
Indiana	1,650	173,000
Missouri	1,530	94,000
Vermont	1,000	134,000

TABLE 1.1

Comparison of cow breeds

Breed	% of U.S. cows	Weight in pounds	Annual pounds of milk per cow	% fat in milk	% protein in milk
Holstein	89.0	1500	24,030	3.7	3.0
Jersey	7.6	1000	16,840	4.8	3.6
Brown Swiss	0.9	1400	18,800	4.1	3.4
Ayrshire	0.4	1150	15,700	3.9	3.2
Guernsey	0.3	1100	16,130	4.6	3.3
Milking shorthorn	0.2	1450	16,060	4.0	3.1

guess that Brown Swiss cows came from Switzerland and are dark brown in color. They are docile, though sometimes stubborn. Ayrshires, a red and white breed, were developed in the Scottish county of Ayr. Ayrshires are quite hardy but also nervous and can be difficult to manage. Guernseys, also named for the Channel Island where they were first bred, range in color from light fawn and white to deep yellow. Their milk is also yellow owing to its higher fat level and the secretion of orange-colored β-carotene from their feed (β, pronounced "beta," is the second letter of the Greek alphabet). Guernseys are efficient milk producers. Milking shorthorns originated in the English county of Durham and are known as dairy shorthorns in the British Isles and South Africa. They are a combination of red, white, and roan. They are considered to be efficient grazers and easy to manage.

Many other breeds are found outside the United States. You can figure out where Danish Red, Dutch Belted, Norwegian Red, and Russian Black Pied originated. Flamande and Montbéliard are French breeds, and Illawarra originated in the Illawarra region of New South Wales, Australia.

But you don't have to make cheese from cow's milk. Milk from many mammals can be used to make cheese, but the ability to collect the milk and coagulate it limits the choices to cows, goats, sheep, water buffalo, and a few others. As Cornell University Professor Frank V. Kosikowski, who was the dean of cheese science, once asked, "how does one milk a guinea pig or a 100-ton whale careering through heavy seas?"

Here (Table 1.2) are typical values for the composition of milk from dairy animals (there will be more comparisons in Chapter 11 and an explanation of scientific names in Chapter 9):