



**Cheesy Science!**

*December 2017/January 2018 Issue*

<http://www.acs.org/chemmatters>

**Teacher’s Guide**



**Teacher's Guide for**

***Cheesy Science!***

**December 2017/January 2018**

**Table of Contents**

[Connections to Chemistry Concepts 3](#_Toc497567077)

[Teaching Strategies and Tools 4](#_Toc497567078)

[Standards 4](#_Toc497567079)

[Vocabulary 5](#_Toc497567080)

[Reading Supports for Students 6](#_Toc497567081)

[Anticipation Guide 8](#_Toc497567082)

[Graphic Organizer 9](#_Toc497567083)

[Student Reading Comprehension Questions 10](#_Toc497567084)

[Answers to Student Reading Comprehension Questions 12](#_Toc497567085)

[Possible Student Misconceptions 13](#_Toc497567086)

[Anticipating Student Questions 14](#_Toc497567087)

[Activities 16](#_Toc497567088)

[References 18](#_Toc497567089)

[Web Sites for Additional Information 21](#_Toc497567090)

[About the Guide 24](#_Toc497567091)

# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **pH** | The fermentation of cheese is highly dependent upon the pH conditions during the reaction. This article provides students with a practical and relatable example of how varying the pH causes reactions to change, and produce different results. |
| **Polar molecules** | An example of the polarity of molecules is found in the formation of micelles of casein in making cheese. The hydrophobic and hydrophilic nature of molecules due to their polarity has a profound effect on solubility, mixtures, and biochemical processes. |
| **Biochemistry** | The action of rennin (an enzyme), casein (a protein), and peptide bonds; the human use of microbial reactions to alter foods; and the dependence of living organisms on proper pH illustrate many aspects of biochemistry, through the study of cheesemaking. |
| **Rates of reaction** | The variables affecting the rate and success of cheese production that are discussed in the article are great examples of factors affecting reaction rates in general. |
| **Relationship between H+ and OH– in water solutions** | The article shows an excellent chart illustrating the relationships among pH, OH– concentration, and H+ concentration. This visual aid may provide students with a way to better understand acids and bases. |
| **Peptides and amino acids** | The production of cheese from the milk protein, casein, is a practical example of peptides, peptide bonds, and the constituent amino acids. When aging cheese, the article provides information on how proteins are converted by bacteria into peptides, then amino acids, and then into amides that influence the taste and texture of these aged cheeses. |
| **Enzymes as catalysts** | While the article does not identify it as such, rennin is a biological catalyst found in rennet. Students may be familiar with inorganic catalysts, but biological catalysts (enzymes) may be a less familiar example. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:

**ELA-Literacy.RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**ELA-Literacy.RST.9-10.5.** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, and energy).

**ELA-Literacy.RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

**ELA-Literacy.RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

* Links to **Common Core Standards for Writing**:

**ELA-Literacy.WHST.9-10.2F.** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

**ELA-Literacy.WHST.11-12.1E.** Provide a concluding statement or section that follows from or supports the argument presented.

* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

**ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.

**ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

* Links to **Next Generation Science Standards**:

**HS-PS1-5:** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

* **Disciplinary Core Ideas**:
* PS1.A: Structure and properties of matter
* PS1.B: Chemical reactions
* **Crosscutting Concepts:**
* Scale, proportion, and quantity
* **Science and Engineering Practices:**
* Asking questions (for science) and defining problems (for engineering)
* Analyzing and interpreting data
* **Nature of Science:**
* Scientific knowledge assumes an order and consistency in natural systems

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the December 2017/January 2018 issue:

* Metric units
* Structural Formulas
* Fermentation
* pH
* Electrochemistry
* Oxidation & Reduction
* Amines
* Allotropes
* Physical properties
* London dispersion forces

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.
* **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 10):** The Student Reading Comprehension Questions are designed to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make decisions in their personal lives.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Cheese consumption in the U. S. is down from 30 years ago.
 |
|  |  | 1. All cheese comes from the milk of mammals.
 |
|  |  | 1. Bacteria are required to make cheese.
 |
|  |  | 1. Milk is slightly basic.
 |
|  |  | 1. Bacteria that grow best in moderate temperatures (between 20 and 45°C) are used to make sharp cheeses like Parmesan and romano.
 |
|  |  | 1. As sugar ferments, the solution becomes more acidic.
 |
|  |  | 1. People who are lactose intolerant can eat aged cheese.
 |
|  |  | 1. Rennet, an enzyme used to speed up the curdling process, comes from a calf’s stomach.
 |
|  |  | 1. All cheeses acidify from milk at the same rate.
 |
|  |  | 1. Some hard cheeses may be aged for decades.
 |

## Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

**Directions**: ***As you read***, complete the graphic organizer below to compare the chemistry of how hard and soft cheeses are produced.

.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Examples of hard cheese*** | ***Steps to produce hard cheese*** | ***pH*** | ***Temperature*** | ***What happens in this step*** |
|  | Adding bacteria |  |  |  |
| Creating curd (coagulation) |  |  |  |
| Finishing cheese |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Examples of hard cheese*** | ***Steps to produce hard cheese*** | ***pH*** | ***Temperature*** | ***What happens in this step*** |
|  | Adding bacteria |  |  |  |
| Creating curd (coagulation) |  |  |  |
| Finishing cheese |  |  |  |

**Summary:** On the back of this paper, write three new things you learned about making cheese that would like to share with a friend.

## Student Reading Comprehension Questions

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

**Directions**: Use the article to answer the questions below.

* 1. On average, how much cheese is consumed per person each year in the United States?
	2. In making cheese, what is the product formed when bacteria digest the sugars in milk?
	3. List the three basic steps involved in cheesemaking.
	4. What is the pH of milk, and is it considered acidic, neutral, or basic?
	5. How does the composition of cow's milk compare to that of hard cheddar cheese?
	6. What type of bacteria are used in making mellow cheeses, like cheddar, Gouda, and Colby?

**Student Reading Comprehension Questions, cont.**

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

* 1. Explain the process of how the casein micelles in hard cheeses coagulate.
	2. What is the whey that is formed during cheesemaking?
	3. How do different cheeses acquire their different tastes and textures?
	4. What happens chemically as cheeses are aged?
	5. What is the relationship between H+ and OH– (measured in mol/L) at a pH of 6?

## Answers to Student Reading Comprehension Questions

1. **On average, how much cheese is consumed per person each year in the United States?**

*The average cheese consumed per person in the United States is about 36 pounds per year.*

1. **In making cheese, what is the product formed when bacteria digest the sugars in milk?**

*In making cheese, when bacteria digest the sugars in milk, the product formed is lactic acid.*

1. **List the three basic steps involved in cheesemaking.**

*The three basic steps involved in cheesemaking are:*

* 1. *adding beneficial bacteria to milk,*
	2. *coagulating the milk into curd, and*
	3. *pressing and cutting the curd into cheese.*
1. **What is the pH of milk, and is it considered acidic, neutral, or basic?**

*The pH of milk is between 6.6 and 6.7 and, (since its pH is below 7, students should recognize that) it is considered acidic (even though it’s not stated as such in the article).*

1. **How does the composition of cow's milk compare to that of hard cheddar cheese?**

*When the composition of cow's milk is compared to hard cheddar cheese, the cow's milk has more water and carbohydrates and the cheese has more fat, protein, and minerals.*

1. **What type of bacteria is used to make mellow cheeses, like cheddar, Gouda, and Colby?**

*The type of bacteria used in making mellow cheeses is mesophilic bacteria.*

1. **Explain the process of how the casein micelles in hard cheeses coagulate.**

*In order for casein micelles in hard cheeses to coagulate, rennet is added to the mixture. The chymosin in the rennet removes the negatively charged ends from the micelle surfaces, reducing the micelles' polarity. The micelles are then repelled by water and begin to stick together and coagulate by forming long chains extending in all directions forming a 3-dimensional matrix.*

1. **What is the whey that is formed during cheesemaking?**

*Whey is the liquid by-product of cheesemaking, which contains soluble proteins. It is sometimes used as a substitute for skim milk, or as a fertilizer.*

1. **How do different cheeses acquire their different tastes and textures?**

*The different tastes and textures of cheeses are due to the different rates of acidification and the different culture organisms used in making the cheeses.*

1. **What happens chemically as cheeses are aged?**

*As cheeses are aged, the bacteria chemically break down the proteins first into peptides, then into amino acids, and then into amines; each succeeding step produces different, more complex flavors.*

1. **What is the relationship between H+ and OH– (measured in mol/L) at a pH of 6?**

*At a pH of 6, the H+ is 1 x 10-6 mol/L and the OH*– *is 1 x 10-8 mol/L.*

# Possible Student Misconceptions

1. **“Cheeses are high in fats and calories and should not be eaten if you are on a diet.”** *Cheeses are rich sources of proteins and minerals (including calcium). They are higher in fat content and calories than milk or other foods, but they can be eaten by individuals on diets. If the calories or fat content is an issue for an individual, some low fat cheeses are available that still supply the protein and minerals people need for a healthy lifestyle.*
2. **“Eating cheese can lead to heart diseases.”** *Evidence from international researchers discredits the misconception that eating cheeses and dairy products—even full fat versions—leads to heart diseases. This misconception is based on the fear of consuming high saturated fats in dairy products. While excessive saturated fats in the diet can be a problem for some individuals, health officials state that dairy products are an important part of a healthy diet. If people are still concerned, they can eat lower-fat varieties of dairy products like low-fat cheese or skim milk.*
3. **“Eating cheese can cause acne.”** *While there are many diets, theories, and anecdotes relating dairy and acne, studies show that there is not a clear link between the two. There are some studies that show an association between acne and consuming dairy products, but there is not a definitive cause and effect. The dairy sources of calcium and vitamin D needed for bone growth, and the protein for muscles are important for most people. When in doubt, consult with your doctor.*
4. **“Cheese is really just spoiled milk”** *In reality, cheese is made from the freshest milk that can be obtained. Spoiled milk may curdle and taste funny, but these are not characteristics desired in cheese. Making cheese from milk requires the strictest cleanliness and hygiene, in order to produce a consistent and edible product. In reality, cheese is preserved milk—it has the proteins, fats, minerals, and carbohydrates of milk concentrated into a longer lasting product that we call cheese!*

# Anticipating Student Questions

1. **“If people are lactose intolerant, can they eat cheese?”** *People who are lactose intolerant can eat hard, not soft, cheeses. The fermentation occurring in making hard cheeses converts almost all of the lactose into lactic acid, making it safe for lactose-intolerant people to enjoy them However, in soft cheeses, much less of the lactose has been fermented, so soft cheeses would not be a good choice.*
2. **“Is the lactic acid produced during fermentation in cheesemaking the same lactic acid that makes muscles sore when exercising?”** *Yes! Regardless of the source, lactic acid is always lactic acid. The lactic acid found in cheese is formed when the most common sugar in milk, lactose, is fermented by bacteria into lactic acid. The lactic acid (sometimes called lactate by athletes) formed in muscles is the product of anaerobically converting glucose (another sugar) for energy through glycolysis.*
3. **“Is the whey formed in making cheese related to the whey protein that many athletes take as a supplement?”** *Indeed, the whey found in protein supplements or whey powder is the same whey left over from making cheese. Whey is a watery material containing soluble proteins when the casein (cheese curds) are extracted. These proteins are extracted from the liquid whey, and concentrated and purified into the whey protein powder. Some whey protein products may add additional protein supplements from soy, egg, or other products.*
4. **“Can a person form a cheese addiction?”** *Some people have stated that cheese is like crack cocaine and is addictive. This is not true. Many people love cheese, but it is not addictive. Addictive eating behaviors are often associated with processed foods containing unusually high levels of fats or sugars such as pizza, chips, and cake. Part of the incorrect assumption that cheese can be addictive may be due to the casomorphins formed in the digestion of cheese binding to opioid receptors in the brain. However binding to a brain site and being addicted are not the same. So, you can safely eat and enjoy your cheese with no worries about addiction! (*[*https://www.sciencenews.org/blog/scicurious/no-cheese-not-just-crack*](https://www.sciencenews.org/blog/scicurious/no-cheese-not-just-crack)*)*
5. **“If I'm allergic to molds and penicillin, can I eat cheese?”** *The mold* Penicillium roqueforti *is used in blue cheeses like Roquefort. However, the enzymes in cheese break down most of the mold used in making the cheese. Typically, these cheeses are safe for most people to eat because the strain of Penicillium used in the antibiotic is* P. chrysogenum*. So, it is possible to be allergic to the antibiotic penicillin and still eat cheeses. When in doubt, however, consult your doctor.*
6. **“If I'm on a strict vegetarian diet, can I still eat cheeses if they’re made with rennet from cow stomach?”** *Strict vegetarians do not consume most animal products. Because rennet can be extracted from calf stomach (or goat or lamb stomachs), it may be an issue for some people. Much of the rennet used in making cheese today is produced genetically in bacteria and is not extracted from animal stomach, which may permit some vegetarians to eat cheeses. Many soft cheeses don't contain rennet but, because some do, consumers need to check the ingredients label or contact the company to be certain. If the rennet from bacteria is an issue for others, it is possible to purchase cheese made from enzymes extracted from plants like nettles. Also, making soft cheese (like cream cheese) at home would not involve rennet. Most certified-kosher cheeses are rennet-free; read labels and ask your grocers if you need vegetarian cheese.*
7. **"I see the terms rennet and rennin both used with cheesemaking. Are they the same thing?"** *No, they are not the same thing; however, rennet and rennin can be confusing. Rennet is a complex mixture of enzymes and other substances found in the gastric juice of many mammals' stomachs. Historically, rennet was extracted from cows' stomachs, but occasionally from goats or lambs, too. Rennin, which is another name for chymosin, is one of the enzymes found in rennet. It is an enzyme that precipitates the milk protein casein. Young mammals use rennin to coagulate casein so that it remains in their stomach longer for better digestion and absorption. So, rennin and rennet are related, but rennin is just one of the enzymes found in rennet.*

# Activities

**Labs and demos**

L**ab making mozzarella cheese:** Science Friday provides the lab, “Get Cheesy: Make Curds and Mozzarella”, which directs students to test how the composition of milks (from different animal or plant sources, or different fat contents of cow's milk) affects curd formation. Students continue the activity by making mozzarella cheese, and an extension allows students to redesign the experiment. (<https://www.sciencefriday.com/educational-resources/get-cheesy-make-curds-and-mozzarella/>)

**Lab precipitating and analyzing proteins from milk and soy milk:** "Proteins" from the Institute of Food Technologists' publication, *Food Chemistry Experiments* is a lab using an acid to precipitate casein (milk protein) from milk and making cottage cheese, which is then analyzed with a biuret test for proteins. Student directions, teacher tips, material lists, and sample student data are provided. (<http://www.ift.org/~/media/Knowledge%20Center/Learn%20Food%20Science/Experiments/TeacherGuidePROTEINS.pdf>)

**Media**

**Video of making cheese at home:** “Cheese Science: The 8 Steps of Cheese Making” (9:32) from the Utah Education Network provides this instructional video for making cheese in your kitchen. This video provides a nice visual, along with simple explanations of the process, and some of the chemistry involved in making the mozzarella cheese. (<https://www.youtube.com/watch?v=Qxr0w4P_tzw&feature=youtu.be>)

**Video lecture of micelle formation:** AK Lectures provides a video lecture, “Micelles and Lipid Bilayer” (13:22), with a diagram of micelles and with chemical terminology. The first part of the video (0:00–5:58) addresses micelles, while the latter portion concentrates on lipid bilayers and compares the two types of structures. (<https://www.youtube.com/watch?v=MTwUy3c5Etc>)

**Lessons and lesson plans**

**Lesson on studying properties of milk:** The National Agriculture in the Classroom Web site provides a lesson on milk, “Milk: The Scoop on Chemical and Physical Changes”. The two-part lesson aimed at grades 9–12 provides vocabulary review, background information, student directions and an infographic, suggested evaluations, and enrichment activities. (<https://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=246&author_state=0&grade=9&search_term_lp=cheese>)

**Making cheese lesson (with extension suggestions):** While this lesson, "Cheesy Chemistry", from PBS Learning Media is targeted for grades 6–8, the lesson is applicable to Gilbert’s "Cheesy Science" article, because it describes the chemistry of making cheese and suggests extended activities that high school students might use as a springboard for further work. This lesson includes a link to a background video, "Cheese: Not the Same Mold Story". ([https://aetn.pbslearningmedia.org/resource/sf10.sci.ps.psci.chmchng.lpcheese/cheesy-chemistry/#.Wd5dwZOWxhG](https://aetn.pbslearningmedia.org/resource/sf10.sci.ps.psci.chmchng.lpcheese/cheesy-chemistry/%23.Wd5dwZOWxhG))

**Projects and extension activities**

**Effects of different substrates and conditions on curd formation:** Students could design experiments to test numerous variables on the size, quality, and characteristics of cheese curds by changing the type of milk (cow, goat, soy) and both the pH and the rate of pH change of the milk, type of acid (lemon juice, vinegar, citric acid) used in curdling, agitation of the milk, and fat content of the cow milk (whole, 2%, skim) using protocol similar to "Cheese Production From Milk". (<http://terpconnect.umd.edu/~nsw/ench485/lab1.htm>) Tests for the curds could include size, texture, moisture content, odor, pH, and—if produced in a sanitary facility and approved by the teacher—the taste of the curds.

**Denaturing different proteins:** Casein in milk is denatured in making cheese and, in this home activity, the temperatures at which common proteins like casein (milk), albumin (egg), and keratin (hair) denature are compared. The activity could be extended by investigating the pH at which these proteins denature, or other methods of denaturation. (<https://www.education.com/science-fair/article/denaturing-proteins/>; note that this Web site requires a free registration for use.)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of
Teacher’s Guides for all issues from the past three
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**

***30* Years of *ChemMatters !***

Available Now!

 This older article provides information on yogurt, a type of fermented fresh dairy product, which is produced by the acid precipitation of casein, rather than using rennet, as in cheesemaking. The article contains a figure showing the formation of casein strands from micelles, and a short discussion of lactose intolerance. (Evans, G. Yogurt. *ChemMatters*, 1989, *7* (3), pp 9–12)

 While "Say Cheese" is an older article, it contains additional information to support the Gilbert article. This article includes comparisons of different cheese compositions, a diagram showing the chemical process of precipitating protein, and an activity to make lemon cheese. (Baxter, R. Say Cheese. *ChemMatters*, 1995, *13* (4), pp 4–7)

 For a diagram and good explanation of micelles and polarity of molecules, readers can turn to "Demystifying Gross Stuff". The section of the article concerned with sebum, which causes acne, includes the sections on micelles and polar molecules and their behavior. (Rohrig, B. Demystifying Gross Stuff. *ChemMatters*, 2011, *29* (3), pp 12–14)

"Who Put the Cheddar in Cheese?" provides additional information on cheesemaking, explaining the composition of milk, the colloidal nature of milk, and showing numerous pictures of the process of making cheese. (De Antonis, K. Who Put the Cheddar in Cheese? *ChemMatters*, 2012, *30* (1), pp 12–13)

 The February 2012 Teacher's Guide for "Who Put the Cheddar in Cheese?" (above) includes additional information on the history of cheese, rennet, the chemistry or rumination, and lactobacilli. In-class activities include making fresh cheese, making yogurt, a milk analysis, and making cheddar cheese curds.

 "Not Milk? Living with Lactose Intolerance" explains the problems some people have digesting the primary sugar in milk and other dairy products, lactose. Chemical structures of lactose, maltose, and sucrose are compared and suggestions for lactose-free foods are discussed. (Rohrig, B. Not Milk? Living with Lactose Intolerance. *ChemMatters*, 2013, *31* (2), pp 18–19)

 The April 2013 Teacher's Guide for "Not Milk? Living with Lactose Intolerance" (above) adds information on lactose, including ways to modify or eliminate it in dairy products, and more background information on lactose and lactase.

 The whey left over from producing cheese may be modified and used as whey powder protein. This article discusses the pros and cons of using sports supplements like whey, and it includes a sidebar explaining three types of whey protein powders. (De Antonis, K. Sports Supplements: Helpful or Harmful? *ChemMatters*, 2013, *31* (3), pp 12–14)

 The October 2013 Teacher's Guide for "Sports Supplements: Helpful or Harmful" includes extensive material on whey protein powder, including sources, composition, and possible health effects.

 For information on fermented foods (cheese is a fermented food) including yogurt, sauerkraut, pickles, kimchee, kombucha, cottage cheese, and buttermilk that contain probiotics with beneficial bacteria, see this article, "Probiotics: Good Bacteria, Good Health". (Haines, G. Probiotics: Good Bacteria, Good Health. *ChemMatters*, 2015, *33* (3), pp 11–13)

 A brief discussion of yogurt and *Lactobacillus* bacteria associated with fermenting milk is found in the October 2015 Teacher's Guide for "Probiotics: Good Bacteria, Good Health" (above).

 "Kombucha: Something's Brewing" devotes the entire article to this fermented food, which is viewed as a probiotic. The author explains beneficial bacteria and fermentation (which also occurs in making cheese). (Nolte, B. Kombucha: Something's Brewing. *ChemMatters*, 2016, *34* (1), pp 14–15)

 The February 2016 Teacher's Guide for "Kombucha: Something's Brewing" (above) adds information on fermentation and types of fermented foods, lactic acid fermentation, and fermentation in ruminant animals.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 This article identifies bitter compounds found in cheeses, from fermentation and other sources, and the compounds found in cheese that mask the bitterness, making them palatable for humans. The cheeses analyzed are Baraka, brie, Gouda, and ricotta. (Homma, R., et al. Identification of Bitterness-Masking Compounds from Cheese. *J. Agric. Food Chem.*, 2012, *60* (18), pp 4492–4499; <http://pubs.acs.org/doi/pdf/10.1021/jf300563n>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

 For a thorough explanation of rennet coagulation in milk and how it relates to cheesemaking and whey production, readers can access "Rennet Coagulation and Cheesemaking Properties of Thermally Processed Milk: Overview and Recent Developments". (Kethireddipalli, P.; Hill, A. Rennet Coagulation and Cheesemaking Properties of Thermally Processed Milk: Overview and Recent Developments. *J. Agric. Food Chem.*, 2015, *66* (43), pp 9389–9403; <http://pubs.acs.org/doi/abs/10.1021/jf504167v?src=recsys&journalCode=jafcau>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

 *The Science of Cheese* is a book for nonscientific readers that provides in-depth information on the biology, chemistry, and physics of all things related to cheese. It includes history, laws, and possible activities to conduct at home. (Tunick, M. *The Science of Cheese*; Oxford University Press: New York, NY, 2013.

# Web Sites for Additional Information

**History of cheese**

The Web site *Today I Found Out* provides "The History of Cheese", starting with a likely Arab journeying across the desert. This short, readable site is a good start for understanding cheese. (<http://www.todayifoundout.com/index.php/2013/04/the-history-of-cheese/>)

 The National Historic Cheesemaking Center (in Wisconsin, of course) also explains the "History of Cheese", with an emphasis on the U.S. and Wisconsin in its explanation. (<http://www.nationalhistoriccheesemakingcenter.org/history-of-cheese/>)

**Facts about milk and cheese**

 The *Milk Facts* Web site has an extensive array of links to specific aspects of dairy products, and "Cheese Production" is only a portion of the information available. There are also links to "Milk Composition", "Nutrition", "Microbiology", "Processing", and "Resources" that provide more information, as well as links on "Fluid Milk Production", "Ice Cream Production", "Yogurt Production", and 'Cheese Production". (<http://www.milkfacts.info/Milk%20Processing/Cheese%20Production.htm>)

 "The Chemistry of Milk" contains extensive information on milk, with basic chemistry and biology concepts highlighted and explained. This resource from the *Dairy Processing Handbook* Web site has figures, illustrations, and a thorough discussion of all things related to milk. (<http://dairyprocessinghandbook.com/chapter/chemistry-milk>. Note that readers must sign in with an email address.)

**Rennet**

 "You Can Thank Genetic Engineering for Your Delicious Cheese" on the *Gizmodo* Web site explains how rennet is used in making cheese. The transition from rennet, obtained from veal through the 1970s, to genetically engineered rennet in the 1990s is an interesting story. [(https://www.gizmodo.com.au/2016/05/you-can-thank-genetic-engineering-for-your-delicious-cheese/](file:///C%3A%5CUsers%5CBill%5CAppData%5CLocal%5CPackages%5CMicrosoft.MicrosoftEdge_8wekyb3d8bbwe%5CTempState%5CDownloads%5C%28https%3A%5Cwww.gizmodo.com.au%5C2016%5C05%5Cyou-can-thank-genetic-engineering-for-your-delicious-cheese%5C))

"Cheese Science" provides an explanation of cheesemaking, including a detailed discussion (with diagrams) of the rennet coagulation of milk. *The CheeseScience.net* site also has a few links to other cheese resources, including information on cheddar and an introduction to cheese science. (<http://www.cheesescience.net/2008/06/rennet-coagulation-of-milk.html>)

**The difference between rennet and rennin**

 The Web site “Sciencing” provides a quick explanation of the difference between rennet and rennin at <https://sciencing.com/difference-between-rennin-rennet-8182538.html>.

**Casein**

 The *Milk Facts* Web site provides "Milk Proteins" and explains the properties of the milk protein, casein. The site includes sections on properties, chemistry, deterioration, and effect of heat on milk proteins—primarily casein. (<http://www.milkfacts.info/Milk%20Composition/Protein.htm>)

The *Danisco* Web site includes "Dairy Chemistry—Part I of IV: Casein", with a table comparing casein and whey protein, and a second table illustrating the causes for casein aggregation into micelles. An explanation of casein is included on the site. (<http://www.danisco.com/food-beverages/dairy/insights-for-cultured-dairy-newsletter/april-2016/dairy-chemistry-part-i-of-iv-casein/>)

**Micelles**

 An introductory explanation from the University Federico II of Naples, Italy, explains micelles and their formation, with helpful diagrams. This Web page is short, colorful, and clear in its information. (<http://www.whatischemistry.unina.it/en/micella.html>)

The *Cheese Science* Web site "Coagulation—Curds Getting Comfy" provides information on the formation of micelles in cheesemaking. There are useful diagrams and explanations of the hydrophobic and hydrophilic forces involved in micelle formation. (<http://www.cheesescience.com/2011/07/29/coagulation-getting-comfy-with-your-curds/>)

**Whey**

 "Whey Processing" on the *Dairy Processing Handbook* Web site is an in-depth look at whey: processing, uses, composition, and much more. Numerous tables of data are provided, along with diagrams of equipment and flowcharts. (<http://dairyprocessinghandbook.com/chapter/whey-processing>. Note that readers must sign in with an email address.)

 "What is Whey Protein?" from *Live Science* explains how whey is derived (from cheesemaking), and its use as a protein supplement for athletes and active people. The site includes a section on the safety and effectiveness of whey protein supplements. (<https://www.livescience.com/45120-whey-protein-supplements.html>)

**Cheeses and pH**

 A 2002 publication, *Dairy Pipeline*, from the Wisconsin Center for Dairy Research has a cover article, "Cheese pH—What's Behind the Rise and Fall" that discusses pH, buffers, measuring pH in cheese, and much more. The publication also has an article on "Salt Crystal Size and Salt Retention in Cheddar Cheese". (<https://www.cdr.wisc.edu/sites/default/files/pipelines/2002/pipeline_2002_vol14_04.pdf>)

 A short, general review of the pH concept and its applications to cheese, from the University of Guelph, is located at <https://www.uoguelph.ca/foodscience/book-page/ph-0>

**Types of cheeses**

 It is estimated that there are over 2,000 different cheeses. This art infographic looking like a cheese wheel lists 66 cheeses and groups them into milk source and types (hard, semi-hard, and soft), and it includes a representation of a slice of each type. (<http://thumbnails.visually.netdna-cdn.com/the-charted-cheese-wheel_51ae17314abed.jpg>)

 *Men's Journal* provides "Name That Cheese: 35 Types to Try", which includes information for each type, including appearance, texture, flavor, aroma, what to buy, and a picture of each type. (<http://www.mensjournal.com/food-drink/collections/35-types-of-cheese-everyone-should-know-w203742>)

**Mesophilic and thermophilic cheese bacteria**

 For an exhaustive treatment of the bacterial cultures used in cheesemaking, including sections about starter bacteria, lactic acid bacteria; bacteria classification based on temperatures; classification based on fermentation; cultures used for specific cheeses; artisanal cheese cultures; salt sensitivity; and much more, see <http://www.innocua.net/web/download-2290/cm-0004-12.pdf>.

**Cheese made with stinging nettles instead of rennet**

 The *International Journal of Gastronomy and Food Science* provides information on making cheese without the use of the animal component, rennet. "Nettle Cheese: Using Nettle Leaves (*Urtica dioica*) To Coagulate Milk in the Fresh Cheese Making Process" explains how the stinging nettle plant can be used as a vegetable coagulation substitute for rennet. (<http://www.sciencedirect.com/science/article/pii/S1878450X16300178>)

**Natural versus processed cheeses**

 The U.S Environmental Protection Agency supplies the publication "Natural and Processed Cheese" to explain the processes and differences in making natural and processed cheeses. Tables, flowcharts, and clear explanations provide readers with accurate information. (<https://www3.epa.gov/ttn/chief/ap42/ch09/final/c9s06-1.pdf>)

**Dairy consumption and heart disease**

 The U.S. National Institutes of Health Web site provides information for people concerned about the consumption of dairy products and links to heart diseases in the 2014 report, "Dairy and Cardiovascular Disease: A Review of Recent Observational Research". In short, 18 studies were reviewed, and the results indicate that dairy consumption does not contribute to cardiovascular disease; readers can read the whole article at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4006120/>.

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

E-mail: bbleam@verizon.net

Susan Cooper prepared the anticipation and reading guides.

Terri Taylor, *ChemMatters* Teacher’s Guide interim editor, coordinated production and prepared the Microsoft Word and PDF versions of the Teacher’s Guide.

E-mail: chemmatters@acs.org

Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.