UNIT OVERVIEW

UNIT TITLE	**Lactose in Milk:** Understanding its chemistry, effects on human health, and how the food industry addresses it
TARGET AUDIENCE	Middle & High School Students (Grades 6 – 12)
INTENDED SITUATION	• Agricultural Clubs (e.g., 4H, FFA, etc.) • Chemistry/Biology classroom • Agriculture Science classroom
UNIT TIMELINE & SCOPE	**Three 1-hour class periods** • Lesson 1: Dairy Discovery – What's milk made of? • Lesson 2: Removing the Lactose – Engineer for the day • Lesson 3: Chemical Detectives – Measuring lactose content
UNIT ABSTRACT	This unit focuses on students learning the fundamentals of dairy composition, health implications of lactose intolerance, and simple engineering principles used to facilitate lactose removal from milk. This is accomplished via integration of several STEM disciplines through the lens of food technology. The first lesson of this unit introduces milk composition and its major macromolecules. The lesson concludes with a discussion of milk's most prominent component (lactose) and its health-related impacts on the human population vis-à-vis lactose intolerance. The second unit concentrates on career exploration by applying engineering principles used by the dairy industry to address the lactose intolerance challenge. Students learn of lactose removal strategies and complete a problem-based learning exercise utilizing design-centric thinking to propose a process to remove lactose. The third lesson comprises a laboratory exercise in which students calculate how much lactose is contained in various volumes of milk and then go about measuring the lactose content of various milks. Students will determine how/if these testing procedures could be used to validate the process they designed in the second lesson. Throughout the three lessons that comprise this unit students critically investigate a major global health issue and propose possible solutions. Lesson 1 defines the problem and its scope, Lesson 2 evaluates possible solutions in the industry, and Lesson 3 outlines a possible method to determine the true efficacy of their proposed solutions.

KEY COMPONENTS

Unit Topics

IN THIS UNIT STUDENTS:

1. Acquire and apply STEM knowledge content and STEM practices in an integrated manner through the lens of a major agriculture commodity/industry: dairy
2. Describe the composition of milk, its major components, and the basic chemistry of each component
3. Recognize the importance of lactose in milk due to its health implications vis-à-vis lactose intolerance, a global health issue
4. Consider the effects lactose intolerance can have on their lives and the lives of those around them
5. Explore key career pathways that require the combination of core STEM skills with AFNR knowledge and understanding — food technologists, food process engineers
6. Examine lactose removal strategies using design-centered thinking and comparing lactose content of various milks in a lab setting

Unit Objectives

AFTER THIS UNIT STUDENTS WILL BE ABLE TO:

1. Identify the major components of milk, their basic chemical properties, and common reactions that occur in milk and milk products (e.g., cheese, yogurt, etc.)
2. Describe the chemical structure of lactose, its substituent parts, and how the human body metabolizes it
3. Identify the health implications of lactose and how lactose intolerance is a global human health issue
4. Illustrate a simplified process flow diagram of a milk processing facility incorporating the main steps in transforming raw milk to bottled, ready-to-drink milk
5. Apply basic engineering principles using design-centered thinking to remove lactose from milk and create a product suitable for those who suffer from lactose intolerance
6. Differentiate dairy products on the basis of lactose content through the use of simple chemical testing methods and materials

TAKE HOME MESSAGE	***Students will integrate chemistry, biology, health, and engineering knowledge through inquiry-based instruction centered on dairy production and processing***

Applicable Educational Standards

Targeted Indiana Standards

INTRODUCTION TO AGRICULTURE, FOOD, AND NATURAL RESOURCES	FOOD SCIENCE	SCIENCE AND ENGINEERING PROCESS STANDARDS	BIOLOGY	CHEMISTRY	HUMAN BODY SYSTEMS (HEALTH)
IAFNR-1.2 - Evaluate and explore the career opportunities in agriculture	FS-5.1 Discuss essential nutrients (proteins, carbohydrates, fats, vitamins, minerals, and water).	SEPS.1 Posing questions (for science) and defining problems (for engineering)	B.1.2 Analyze how the shape of a molecule determines its role in the many different types of cellular processes (e.g., metabolism, homeostasis, growth and development, and heredity) and understand that the majority of these processes involve proteins that act as enzymes.	C.4.2 Predict products of simple reactions	HBS.3.3 Describe the mechanical and chemical activity of the digestive organs, including the action of accessory organs.
IAFNR-8.2 Apply principles of nutrition, biology, microbiology, chemistry and human behavior to the development of food products and processing industry	FS-5.2 Explain the application of chemistry and physics to food science.	SEPS.5 Using mathematics and computational thinking		C.4.4 Apply the mole concept to determine the mass, moles, number of particles or volume of a gas at STP, in any given sample, for an element or compound.	

National Standards (NGSS)

PHYSICAL SCIENCES	LIFE SCIENCES	ENGINEERING, TECHNOLOGY, AND APPLICATIONS OF SCIENCE
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes	HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells	MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
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		HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Lesson Objectives

Lesson 1: Dairy Discovery – What's milk made of?

AFTER THIS LESSON STUDENTS WILL BE ABLE TO:

1. Identify the major macromolecule components of milk and the basic chemistry of each with regards to physical/chemical properties and associated reactions
2. Differentiate between the protein portion, lipid portion, and carbohydrate portions of milk and how each can be recognized in dairy products by using the five senses
3. Identify what lactose intolerance is, its associated symptoms, and how prevalent of a health issue it is for the global population

Lesson 2: Removing the Lactose – Engineer for the day

AFTER THIS LESSON STUDENTS WILL BE ABLE TO:

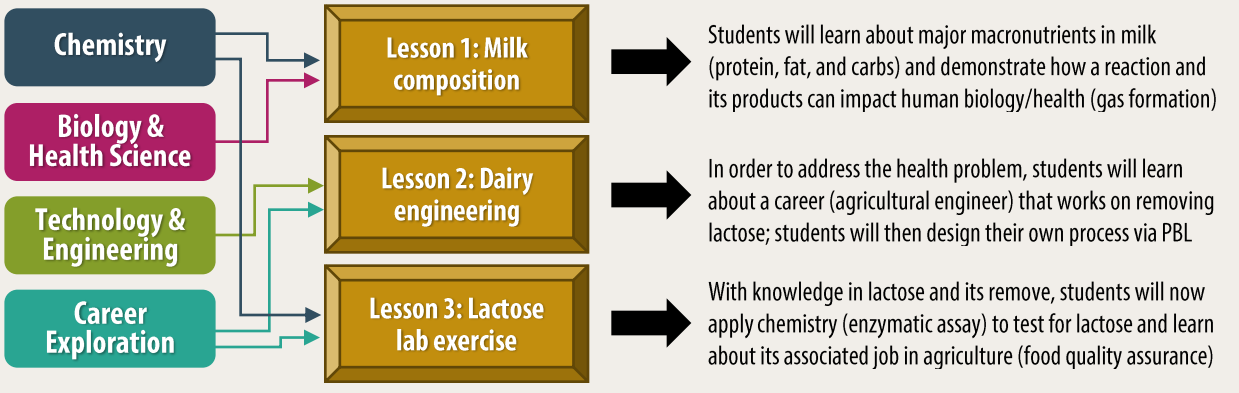
1. Describe the possible career options that exist with regards to manufacturing food products from agricultural commodities (food technologist, food engineer, etc.)
2. Distinguish between the physical removal of lactose from milk (filtration) and the enzymatic removal of lactose from milk (enzymatic treatment)
3. Design a cursory process flow diagram detailing the basic engineering principles involved with producing lactose-free milk (pasteurization, homogenization, etc.)

Lesson 3: Chemical Detectives – Measuring lactose content

AFTER THIS LESSON STUDENTS WILL BE ABLE TO:

1. Apply the lactose hydrolysis reaction in measuring lactose content across various types of dairy products (lactose = galactose + glucose)
2. Collect and analyze data from basic laboratory procedures using test strips and/or color change indicators
3. Recommend which dairy products would be suitable for those suffering from lactose in tolerance and which dairy products should be avoided

STEM & AFNR Integration



Unit Timeline & Outline

	Duration	Lesson Outline
LESSON 1: MILK COMPOSITION	60 – 75 minutes	✓ **Lesson introduction** (5 minutes) ✓ **Milk sketch pre-assessment** (5 minutes) ✓ **Dairy composition PowerPoint** (35 minutes) ▪ Fatty acid demonstration (goat cheese tasting) ▪ Protein activity (milk coagulation) ▪ Lactose fermentation activity (gas formation) ✓ **Lactose Intolerance statistics activity** (10 minutes) ✓ **Milk sketch post-assessment & sharing** (10 minutes)
LESSON 2: DAIRY ENGINEERING	60 – 90 minutes	✓ **Lesson introduction & review** (10 minutes) ✓ **Milk processing video** (10 minutes) ✓ **Lactose removal PowerPoint** (35 minutes) ▪ Milk packaging activity ▪ Filtration video ▪ Lactaid milk video ✓ **Lactose removal process sketches** (15 minutes) ✓ **Wrap-up** (10 minutes)
LESSON 3: LACTOSE LAB EXERCISE	90 minutes	✓ **Review and lab protocol introduction** (5 minutes) ✓ **Group discussion & predications** (10 minutes) ✓ **Lactose detection lab** (60 minutes) ▪ Demonstrate lactase assay ▪ Demonstrate glucose test strip usage ▪ Students perform lab and collect data ▪ Student groups share data centrally ✓ **Discussion & wrap-up** (15 minutes)

Learner-Centered Approaches

	Approach(es) Used	Description
Lesson 1: Milk Composition	Guided Inquiry Cooperative Learning	The cheese tasting, milk coagulation, and gas formation activities encourage students to make their own predictions and draw their own conclusions, with minimal input from the teacher other than materials and procedures. The final portions of the lesson give a few different opportunities for student to learn from each other's experiences
Lesson 2: Dairy Engineering	Problem-based Learning Learning Cycle Self-monitoring	By giving the students a complex global problem to address (lactose intolerance), they can learn about several ways to address the problem and then go about designing a milk processing diagram that addresses the issue. As more information is given and discussed, they can revise and iterate their sketches. Students will critique each other's designs.
Lesson 3: Lactose Lab Exercise	Structured Inquiry Experiential Learning	This laboratory exercise serves as a summary for the unit and allows synthesis of previously covered topics. Students will wear the hat of a food quality control specialist and test lactose levels of various milks to see which ones are suitable for those with lactose intolerance.

Background Information

Milk is a chemically complex, yet very familiar, agricultural commodity. Its main substituents include water, carbohydrate (lactose), protein (casein and whey), and fat. Each of these are important parts of milk and dairy products made from milk. This unit focuses on lactose and its health implications for those who suffer from lactose intolerance. Approximately 65% of the global population has a reduced ability to digest lactose effectively. This population lacks the necessary enzyme in their intestine to digest lactose properly: lactase. Instead, lactose is fermented by bacteria in the large intestine (colon) forming gas and acid. This can lead to extremely discomfort and gastrointestinal distress.

Students will learn about methods the food industry has used to address this issue (lactase enzyme added to milk, filtering lactose, fermented dairy products to remove lactose). To wrap up the unit, students will conduct a wet chemistry lab exercise measuring the presence of lactose in common dairy products.

LESSON 1

DAIRY DISCOVERY – WHAT'S MILK MADE OF?

Lesson Objectives

1. *Identify the major macromolecule components of milk and the basic chemistry of each with regards to physical/chemical properties and associated reactions*
2. *Differentiate between the protein portion, lipid portion, and carbohydrate portions of milk and how each can be recognized in dairy products by using the five senses*
3. *Recognize what lactose intolerance is, its associated symptoms, and how prevalent of a health issue it is for the global population*

Required Materials

- Computer, projector, & screen
- Paper, markers, crayons, etc.
- Plates, cups, spoons
- 20oz plastic bottles
- Balloons
- Alka-Seltzer tablets, water
- Chevre goat cheese, Provolone cheese, Manchego cheese
- Milk, rennet
- Colored notecards

Provided Materials

- Milk composition PowerPoint (page 11)
- Milk composition handout & cheese tasting handout (page 12 - 13)
- Milk sketch handout (page 14)

STEM Integration Call-Outs

CHEMISTRY

Chemical Reactions: during the lesson introduction, be sure to review/draw upon learners' previous knowledge of chemical reactions and common types of them (e.g. breakdown/hydrolysis) and also the involvement of enzymes in some cases (more below) and highlight how flavor can occur due to reactions

Boyle's Law: reintroduce the concept of the relationship between a gas's pressure and its volume (inversely related) and pressure causes force. This force can cause pain inside you!

BIOLOGY/ HEALTH

Enzymes: discuss the role of enzymes in speeding up reactions in the human body and how they cause reactions to occur, like the breakdown of lactose

Digestive System: build upon previous knowledge of the digestive system and discuss how we eat food and the path it takes (mouth, stomach, small intestine, large intestine) and the differences between each. For example, lactose broken down in the small intestine by enzyme is okay, but fermentation of it in the large intestine will cause problems

LESSON 1

DAIRY DISCOVERY – WHAT'S MILK MADE OF?

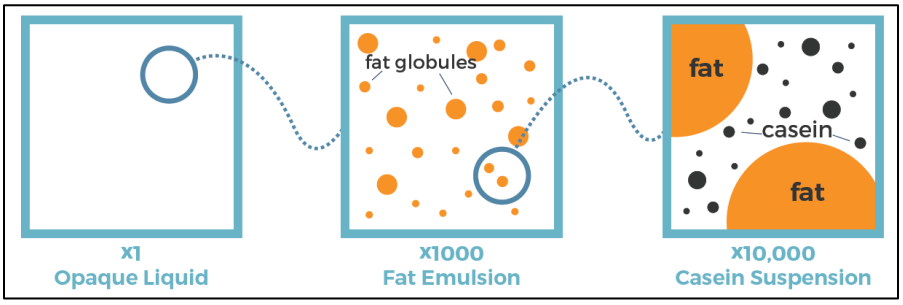
Lesson Procedures

Lesson Introduction (5 min)

- Discuss the plan for the lesson and the goals/lesson objectives
- Prepare for milk sketching pre-evaluation (gather drawing materials and handout)

Milk Sketch Pre-assessment (5 min)

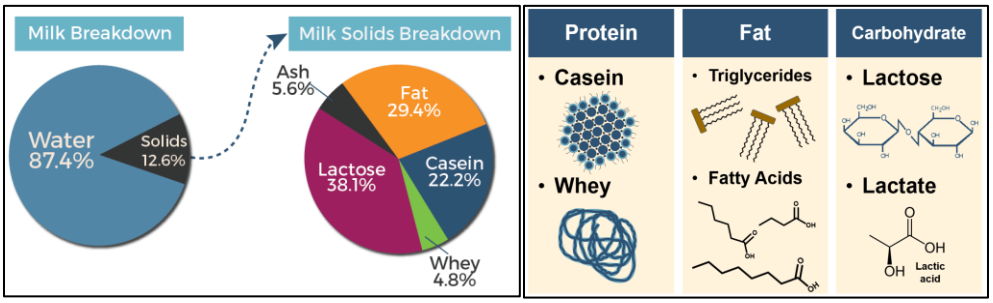
- Distribute milk sketch handout and tell students you just gave them a glass of milk (it's white isn't it?)
- Ask students to draw what milk would look like underneath a microscope



An example of simple milk structure diagram

Dairy Composition Lecture (35 min)

- Prepare ahead of time:
  - Three cheeses that demonstrate different fatty acids (provolone – short chain, cow; chevre – medium chain, goat; manchego – branch chain, sheep)
  - Portion milk into disposable cups; one per student or one per group if working together
- Display and talk through the provided PowerPoint presentation about milk composition. After each portion (fat, protein, carbohydrate), conduct the demonstration or activity outlined below.

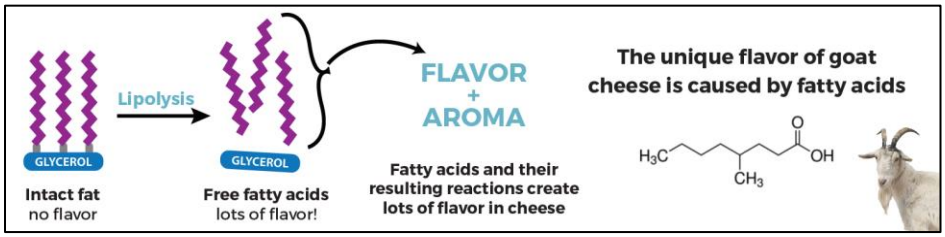


An example of what is covered in the provided PowerPoint

- After discussion of fat and fatty acids, lead a taste test through each of the three cheeses using the placemat provided. Ask the following questions:
  - Do you taste differences between the cheeses?
  - If so, try to describe the differences: what do the flavors/aromas remind you of?
  - We now know the fat composition of each animal's milk is different, can you detect these differences?
  - How could we test this hypothesis with the cheeses we are currently tasting? What would we need?
  - Tasting these flavors is the outcome of what type of reaction? (hydrolysis/lipolysis)

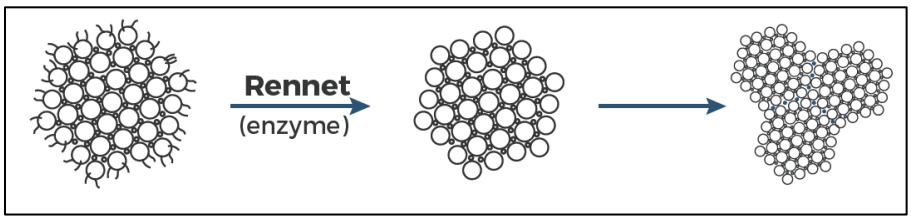
LESSON 1

DAIRY DISCOVERY – WHAT'S MILK MADE OF?



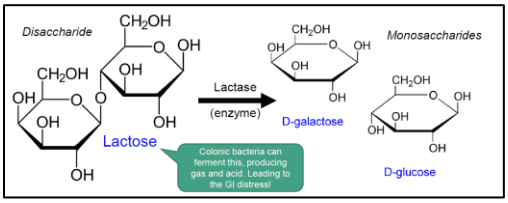
An example of what is covered in the provided PowerPoint

- After the discussion of protein and casein, have each student add several drops of rennet to their (their groups') cup of milk. Swish the cups briefly to mix. Set cups aside for a minute and ask the following questions:
    - What is rennet? Where did it come from?
    - It's an enzyme, what do enzymes do?
    - What does coagulation mean? (they saw an animation, now encourage them to contextualize
    - Have them pick up their cups and investigate their coagulated milk.
    - Ask them how this might be a useful reaction in the food industry? (e.g., yogurt, cheese, etc.)
    - Reinforce that enzymatic reactions can drastically alter reactants into new products



An example of what is covered in the provided PowerPoint

- After the discussion of lactose and lactose intolerance, reinforce the concept of fermentation reactions and gas production by distributing empty soda bottles filled with water + vinegar, along with Alka-Seltzer tablets and balloons. Before adding the tablet to the solution ask students to predict what will happen. After adding tablet and inflating balloon, ask the following questions:
    - Why did the balloon get bigger?
    - How did the gas form? (double replacement reaction)
    - Why did the gas make the balloon get bigger?
    - What are other examples of pressure in the world?
    - Do you think pressure could cause pain?
    - If you ferment lactose and form gas inside your intestine, how do you think you would feel?
    - Do you or anyone you know suffer from lactose intolerance?
    - How many people do you think suffer from lactose intolerance?
    - Show this video to reinforce: https://www.youtube.com/watch?v=w_KR6k6YIIs



An example of what is covered in the provided PowerPoint

LESSON 1

DAIRY DISCOVERY – WHAT'S MILK MADE OF?

Lactose Intolerance Activity (10 min)

- Pass out colored notecards to the students. You will need two colors.
  - 70% of students should receive one color (i.e., orange)
  - 30% of students should receive another color (i.e., white)
- Ask students to raise their hand if they have an orange notecard, repeat with white.
- Now tell the students that one group represents those with lactose intolerance and the other group can digest lactose fully
  - Have students guess which group is which
  - Reveal that the larger group are those that can't fully digest lactose
- **If time permits, have students figure out the approximate lactose intolerance prevalence rate using the class as a model**
  - Tell the students that there are 8 billion people in the world
  - Now ask them to calculate how many people have diminished lactase persistence based on what they now know
  - Unstructured Inquiry: give no further direction
  - Structured Inquiry: ask students how many are in the class and how many are part of the larger group (orange notecards), have them calculate the percentage and apply to 8 billion

Milk Sketch Post-Assessment & Wrap-Up (10 minutes)

- Redistribute a blank copy of the milk sketch handout and tell students to now draw what they think milk would look like underneath a microscope given what they have learned
- Close out the lesson by asking students to share how they think those who suffer from lactose intolerance deals with everyday life and what strategies might be available for them to eat dairy products
- End with passing out final assessment worksheet

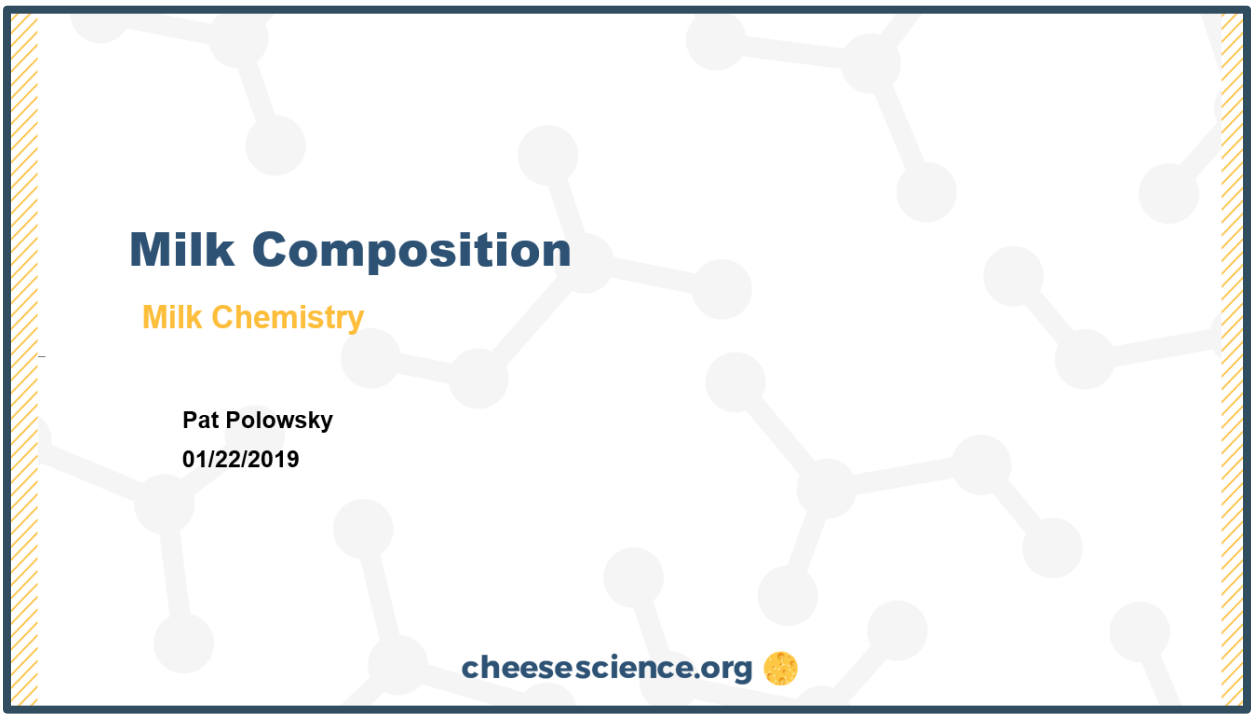
Assessment Strategy

Formative assessments will occur throughout the lesson via questions asked to them during each of the activities. Examples of such questions are listed above in the lesson procedure steps.

The milk sketch activity acts as a summative assessment for this lesson. The amount of knowledge gained by students with regards to milk chemistry and structure can be inferred depending on the increased level of detail of their sketches pre and post lesson. For example, students may now list more components of milk (lactose and casein) or perhaps will now show a better understanding of the scale of these components (fat globules > casein micelles > lactose molecules)

LESSON RESOURCES

MILK COMPOSITION POWERPOINT



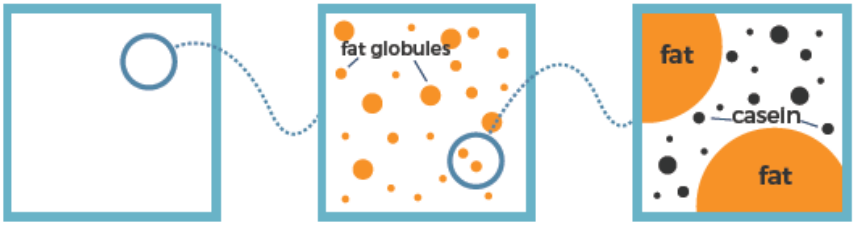
Click on image above to download a copy of the PowerPoint

LESSON RESOURCES

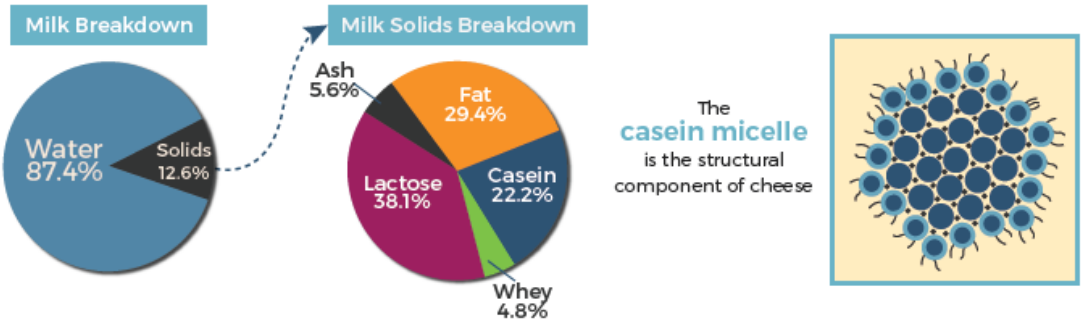
MILK COMPOSITION HANDOUT

MILK CHEMISTRY 101

Simply, milk is an emulsion with fat particles (globules) and proteins dispersed in an aqueous (watery) environment.

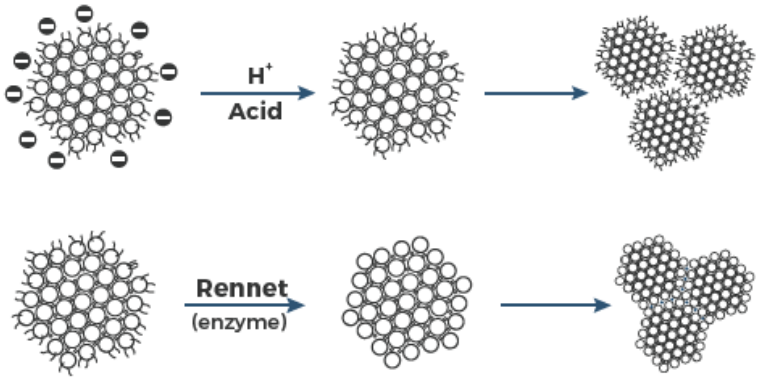


Milk is composed of water, sugar, fat, protein, and minerals



The **casein micelle** is the structural component of cheese

Casein proteins will aggregate under two main conditions: acid coagulation and enzymatic coagulation



Coagulation is what turns liquid milk into solid cheese curd

www.cheesescience.org

LESSON RESOURCES

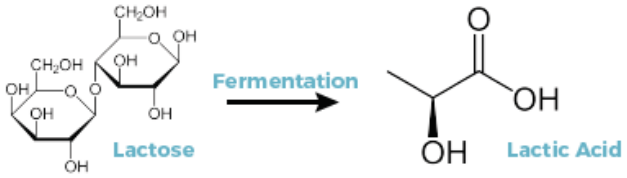
CHEESE TASTING HANDOUT

CHEESE CHEMISTRY 101

Three main reactions take place during cheese aging

FERMENTATION

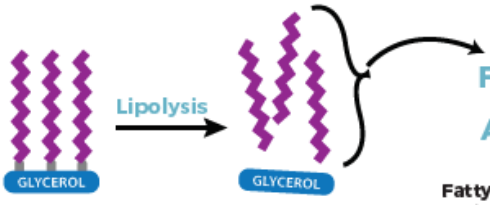
Fermentation (or glycolysis) is the breakdown of the natural milk sugar (lactose) into lactic acid through the use of bacteria (i.e. starter cultures)



The "sharpness" in cheddar comes from the acidity produced by the culture Lactococcus lactis

LIPOLYSIS

Lipolysis is the breakdown of fat into fatty acids, which are crucial to flavor



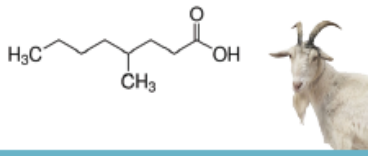
Intact fat no flavor

Free fatty acids lots of flavor!

FLAVOR + AROMA

Fatty acids and their resulting reactions create lots of flavor in cheese

The unique flavor of goat cheese is caused by fatty acids



PROTEOLYSIS

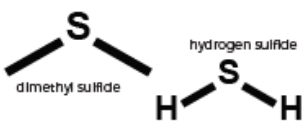
Proteolysis is the breakdown of protein, which greatly impacts cheese flavor and texture

Intact protein no flavor

Peptides flavor (bitter!)

Amino acids and their breakdown products lots of flavor!

The sulfur or "boiled egg" flavor in cheddar comes from the breakdown of sulfur-containing amino acids



www.cheesescience.org

LESSON RESOURCES

MILK SKETCH HANDOUT

NAME:_____

A glass of milk looks white at first glance, but what would happen if you could look even closer?

USE YOUR IMAGINATION AND BRAIN POWER TO DRAW WHAT SECRETS MILK MIGHT BE HIDING…

Make sure you label the parts of your drawing!

LESSON 2

REMOVING LACTOSE – ENGINEER FOR THE DAY

Lesson Objectives

4. *Describe the possible career options that exist with regards to manufacturing food products from agricultural commodities (food technologist, food engineer, etc.)*
5. *Distinguish between the physical removal of lactose from milk (filtration) and the enzymatic removal of lactose from milk (enzymatic treatment)*
6. *Design a cursory process flow diagram detailing the basic engineering principles involved with producing lactose-free milk (pasteurization, homogenization, etc.)*

Required Materials

- Computer, projector, & screen
- Paper, markers, crayons, etc.
- Several milk packages:
  - whole milk carton
  - skim milk carton
  - Lactaid milk carton
  - UF milk carton (Fairlife)
  - soy milk carton

Provided Materials

- Milk processing PowerPoint (page 18)
- Milk processing sketch handout (page 19)
- Career exploration handout (page 20)

STEM Integration Call-Outs

ENGINEERING

Design-centered thinking: students will design a milk processing diagram based off of a video they watch and lecture material in class, incorporating ideas such as fluid flow (pressure), heating (conduction), all the while solving the problem of lactose removal

Food Manufacturing: by discussing common food processing steps (filtering, heating, mixing, etc.) students will get a foundation in food engineering concepts

CAREER EXPLORATION

Agricultural Engineering: students will take on the role of a food processing engineer to draw/diagram a milk processing line and be able to describe its different pieces

Food Technology & Product Development: by analyzing food ingredients labels (on the milk cartons), students will begin to see the details that food technologists and product developers use to make products and the legal requirements they have to keep in mind when making food labels

LESSON 2

REMOVING LACTOSE – ENGINEER FOR THE DAY

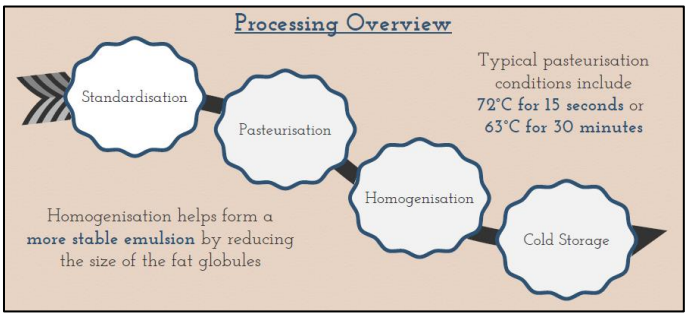
Lesson Procedures

Lesson Introduction & Review (10 min)

- Discuss the plan for the day and lesson overview
- Review key concepts from last lesson:
  - Milk has different types of molecules (protein, fat, lactose)
  - Lactose is a sugar and can make some people sick
  - We need to remove and/or destroy lactose so everyone can enjoy milk
  - Remember lactose can be broken down via a chemical reaction using an enzyme called lactase

Milk Processing Overview (10 minutes)

- Show the following video which is a general overview of how milk is processing made ready to be shipped to grocery stores: https://www.youtube.com/watch?v=dJiYXFgvGLA; ask the following questions afterwards:
  - Knowing what we know about milk's components and basics of chemistry, how do the following processing steps effect those?
  - Fat separator (removes fat), Homogenizer (breaks down fat) – why is this important?
  - Pasteurizer (heats milk and destroys bacteria) – uses metal plates and hot water to heat milk. What kind of heat transfer is that? (conduction)
  - How is the milk being moved through all this? (pumps)
  - Why do pumps work? (they create pressure!)



Basic steps of milk processing

Lactose Removal Lecture (35 minutes)

- Prepare ahead of time:
  - Milk packages described above
  - Have the following videos ready to view:
    - Ultra-Filtered (UF) Milk: https://www.youtube.com/watch?v=e3c-ziMCyRc
    - Lactase in milk: https://www.youtube.com/watch?v=wYyqZWWU9GU
- Display and talk through the provided PowerPoint presentation about lactose removal in milk. After each portion (filtration and enzyme/lactase), display the videos linked above.
- After the lecture, ask the following questions:
  - Why are we removing the lactose again? (reinforces the health issue of lactose intolerance)
  - Can you think of benefits and drawbacks of each removal technique?
  - Why would you use both in some cases?
- To summarize this activity, pass out the milk cartons and have students look at the ingredient statements. Ask the following questions
  - What is the protein content of each milk per 1 cup serving?
  - What ingredients do they contain?

LESSON 2

REMOVING LACTOSE – ENGINEER FOR THE DAY

- What is/are the difference(s) between the food labels? (lactase enzyme, protein content, etc.)
- Why is the UF Fairlife milk higher in protein? (they filter the lactose out, but also concentrate the protein)

Nutrition Facts
Serving Size 1 cup (240 mL)
Servings Per Container About 7

Amount Per Serving	
Calories 80	Calories from Fat 0
	% Daily Value*
Total Fat 0g	0%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 5mg	2%
Sodium 120mg	5%
Potassium 400mg	11%
Total Carbohydrate 6g	2%
Dietary Fiber 0g	0%
Sugars 6g	
Protein 13g	26%

Vitamin A 20% • Calcium 40%
Vitamin D 25% • Riboflavin 20%
Vitamin B12 20% • Phosphorus 25%
Magnesium 6% • Zinc 10%
Not a significant source of Vitamin C & Iron
* Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: NONFAT ULTRA-FILTERED MILK, LACTASE ENZYME, VITAMIN A PALMITATE, VITAMIN D3. **CONTAINS MILK.**
fairlife LLC, Chicago, IL 60607
Let's Chat! 855-LIVEFAIR

Nutrition Facts
8 servings per container
Serving size **1 cup (240 mL)**

Amount Per Serving	
Calories	**150**
	% Daily Value*
Total Fat 8g	10%
Saturated Fat 5g	25%
Trans Fat 0g	
Cholesterol 30mg	10%
Sodium 120mg	5%
Total Carbohydrate 12g	4%
Dietary Fiber 0g	0%
Total Sugars 11g	
Includes 0g Added Sugars	0%
Protein 8g	16%
Vitamin D 0mcg	0%
Calcium 390mg	30%
Iron 0mg	0%
Potassium 357mg	8%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

INGREDIENTS: Organic Whole Milk

Examples of milk nutrition labels from UF ultra filtered milk (left) and regular milk (right). Notice the higher protein content and inclusion of lactase incase any lactose made it through the filter!

- End activity by discussing how food scientists and food product developers are legally responsible to make sure the product labels and nutrition matches what is in the product. They have to work with the food processing engineers to make all this possible

Milk Processing Line Sketches & Wrap-Up (15 minutes + 10 minutes)

- Distribute milk processing sketch handout and instruct the students they must apply what they have learned to solve a problem! How to remove the lactose?
- Instruct them to draw a process starting with raw milk and ending with milk that can be drank by those suffering from lactose intolerance
- Have student present their sketches to the class and ask for feedback from their fellow engineers
- Use this opportunity to reinforce the way engineers solve problems (i.e., global health issue!)

Assessment Strategy

Formative assessment will be conducted via questions asked during the various activities in this lesson (e.g., why are we removing the lactose again?)

The Milk Processing Sketch worksheet can act as a summative assessment in order to gauge how much of the milk processing process students know (i.e., list all the steps, in the correct order, added a "lactose removal" step somewhere)

LESSON RESOURCES

MILK PROCESSING POWERPOINT

Click on image above to download a copy of the PowerPoint

LESSON RESOURCES

MILK PROCESSING SKETCH HANDOUT

NAME:_____

You're a dairy processing engineer. You have been tasked with creating lactose free milk. You will receive milk from a local farm and then process, package, and sell it to local stores.

USE WHAT YOU KNOW TO DESIGN A PROCESS TO MAKE THIS PRODUCT!

Start here:

Raw Milk

→

→

Milk Ready to Sell

LESSON RESOURCES

FOOD SCIENTIST CAREER INFO SHEET

WHAT IS FOOD SCIENCE?

Food Science draws from many different disciplines in an attempt to better understand food processes and ultimately improve food products for the general public

WHAT FOOD SCIENTISTS STUDY

- Chemistry
- Biochemistry
- Nutrition
- Microbiology
- Engineering
- And More...

WHAT KIND OF JOBS FOOD SCIENTISTS FILL

PRODUCT DEVELOPMENT

QUALITY/SAFETY ASSURANCE

GOVERNMENT INSPECTOR

WHERE TO FIND MORE INFORMATION

INSTITUTE OF FOOD TECHNOLOGISTS
IFT.ORG

PURDUE FOOD SCIENCE DEPARTMENT
AG.PURDUE.EDU/FOODSCI

Journal of Food Science EDUCATION
JOURNAL OF FOOD SCIENCE EDUCATION
PUBLISHED BY IFT

LESSON 3

CHEMICAL DETECTIVES – MEASURING LACTOSE

Lesson Objectives

7. *Apply the lactose hydrolysis reaction in measuring lactose content across various types of dairy products (lactose = galactose + glucose)*
8. *Collect and analyze data from basic laboratory procedures using test strips and/or color change indicators*
9. *Recommend which dairy products would be suitable for those suffering from lactose in tolerance and which dairy products should be avoided*

Required Materials

- Ice cube tray
- Several milk types:
  - Cow's milk
  - Lactaid milk
  - UF milk carton (Fairlife)
  - Soy milk carton
- Glucose test strips
- Lactase tablets and/or liquid lactase enzyme preparation
- Hot water

Provided Materials

- Lactose lab handout (page 23 – 25)

STEM Integration Call-Outs

CHEMISTRY

Enzymatic Reactions: students will be utilizing an enzymatic assay in order to indirectly measure lactose content. They will be measuring glucose content (product of lactose breakdown) and inductively reasoning original lactose content

Indicators: by using glucose test strips, students will be exposed to using an instant, visual indicator in order to measure the concentration of a substance

CAREER EXPLORATION

Food Product Quality Assurance: students will take on the role of a food quality assurance supervisor in order to ensure the lactose free milk they are producing (from Lesson 2) is indeed lactose free)

Food Analytical Chemist: enzymatic assays are crucial in many areas of analytical chemistry and food analytical chemists relay on these reactions to test for and quantify a wide range of chemicals and end products (e.g., lactose, sugar, protein, fat, and many other important food nutrients)

LESSON 3

CHEMICAL DETECTIVES – MEASURING LACTOSE

Lesson Procedures

Review & Lab Protocol Introduction (5 min)

- Review information from previous less:
  - They designed an engineering diagram of a milk processing plant to produce lactose free milk
  - Lactose can be removed via filtration and/or enzymatic breakdown
- They now get to switch hats and become a quality assurance supervisor for their milk plant and get to confirm they are indeed producing lactose free milk.

Group Discussion & Predictions (10 minutes)

- Inform the students they will be testing four different milks:
  - Cow's milk (positive control – contains lactose)
  - Soy milk (negative control – does not contain lactose)
  - Lactaid milk (competitor product – does not contain lactose)
  - Test milk, this is the milk their plant is producing (need to determine if there is lactose)
    Instructor note: suggest using a 50/50 blend of lactaid milk and normal milk to give an intermediate result)

Lactose Detection Lab (60 minutes)

- Use the provided lab handout to conduct the lactose detection lab
- During the lab demonstrate the following for the students depending on their level of previous knowledge and comfort depending on age/grade level:
  - How to crush/dissolve lactase pill in hot water
  - How to use the glucose test strip and read the results
- As students are preforming the lab ask probing questions and circulate:
  - Why is it important to include the positive control in the experiment?
  - Why is it important to include the negative control in the experiment?
  - What are the benefits and drawbacks of using the test strips in this exercise?
    - Pros – quick, cheap, and easy to operate
    - Cons – cannot determine exact amount, what if they were using a colored liquid?
- Ensure students are recording the data in their lab notebooks
- Have students complete lab exercise questions

Discussion & Wrap-Up (5 minutes)

- Discuss answers to discussion questions
- Ask students what kind of careers they could apply these skills to

Assessment Strategy

Formative assessment will take place during the laboratory activity by the instructor observing students' technique and competency in completing the lab steps and actions, as well as answering probing questions asked during the exercise.

The post-lab questions can act as a summative assessment in order to ascertain if students learned the basic chemical concepts contextualized by the lab exercise.

LESSON RESOURCES

LACTOSE LAB HANDOUT

NAME:_____

Introduction

Lactose intolerance is a problem for many individuals. Without lactase, drinking milk or eating other dairy products can cause a great deal of discomfort in the form of gas, bloating, and/or diarrhea. Without lactase the bacteria in the gut ferments lactose. The fermentation produces gas which leads to pain and discomfort in the digestive system.

Lactose is a disaccharide sugar, made up of the monosaccharides glucose and galactose. The enzyme lactase breaks the bond that creates lactose. Therefore, when lactase is added to milk, the disaccharide lactose is broken down into the monosaccharides glucose and galactose, and lactose intolerance people can now consume milk!

Problem to Solve:

You are a quality control supervisor at a lactose-free milk factory. Your job is to determine if your newest lactose-free milk is indeed lactose free. You need to if those who are lactose intolerant can consumer your product!

Lab Supplies:

- 1 ice cube tray
- Milk samples (cow's milk, soy milk, Lactaid milk, your milk)
- 8 Glucose test strips
- 1 lactase tablet
- 100 mL of hot water

Procedure:

1. Make the enzyme solution by crushing 1 lactase tablet and stirring it into 100 mL of hot water. Let the solution sit for at least 5 minutes.
2. Label your glucose strips with the well numbers 1-8. **(SEE BELOW/NEXT PAGE)**
3. Add 20 mL of cow's milk to wells 1 and 5.
4. Add 20 mL of soy milk to wells 2 and 6.
5. Add 20 mL of Lactaid milk to wells 3 and 7.
6. Add 20 mL of your milk to wells 4 and 8.
7. One at a time, dip your test strips into the control wells (1, 2, 3, & 4.) After 30 seconds record the amount (mg/dL) of glucose for each well on the chart below.
8. Add 5 mL of enzyme solution to the test wells (5, 6, 7, & 8.) Stir the liquid in each well. Let sit for at least 5 minutes.
9. One at a time, dip your test strips into the test wells (5, 6, 7, & 8.) After 30 seconds record the amount (mg/dL) of glucose for each well on the chart.
10. Calculate the difference between the glucose content of the control samples and the test samples. Record it in the table.
11. After all the data has been recorded, clean up your work area and materials.

Negative lactose (top) and positive lactose examples (bottom)

LESSON RESOURCES

LACTOSE LAB HANDOUT

NAME:_____

Results & Data

Product	Cow's Milk	Soy Milk	Lactaid Milk	Your Milk
	Amount (mg/dL) Glucose			
Control	#1	#2	#3	#4
Test	#5	#6	#7	#8
Difference				

Conclusion

How did your milk do? →

LESSON RESOURCES

LACTOSE LAB HANDOUT

NAME:_____

Lab Report Questions

1. Why is it important to have a "control" in your experiment?

   Answer: to make sure the test strips don't give false positives

2. What are the independent and dependent variables in this experiment?

   Answer: Independent – milk type, Dependent – lactose content

3. Which milk(s) contained glucose at the beginning of the experiment?

   Answer: Lactaid and "Your"/their milk

4. Which milks contained glucose at the end of the experiment?

   Answer: All except Soy

5. Compare the test results of the Lactaid milk and your milk. Did one milk contain more lactose/glucose than the other?

   Answer: Depends on the experimental setup, but theirs probably contains more

6. Explain the results of the Lactaid milk. Did the added lactase have an effect on the milk? Explain why or why not

   Answer: The results should not have changed since Lactaid milk already has lactase added to it

7. Would you be comfortable selling your milk as lactose free? Explain why or why not

   Answer: Depends on the outcome, but most likely No since there is probably residual lactose

8. If not, how would you about fixing the problem?

   Answer: Add more enzyme, heat product, filter out lactose, etc.

LESSON RESOURCES
ASSESSMENT GUIDE

Lesson 1 – What's Milk Made Of?

Formative Assessment Q&A Answer Guide

Do you taste differences between the cheeses?

If so, try to describe the differences: what do the flavors/aromas remind you of?

- They should indicate "Yes" and encourage them to use all possible senses to formalize the differences (X tastes like…; Y feels like…)

We now know the fat composition of each animal's milk is different, can you detect these differences?

- Hopefully fatty acids are brought up. If not, prompt for it.

How could we test this hypothesis with the cheeses we are currently tasting? What would we need?

Tasting these flavors is the outcome of what type of reaction? (hydrolysis/lipolysis)

- These two questions are related. They could test for lipolysis by aging the cheese longer and seeing if the flavors get stronger (gives longer time for enzymes to react!)

What is rennet? Where did it come from?

It's an enzyme, what do enzymes do?

What does coagulation mean? (they saw an animation, now encourage them to contextualize

- These questions show a progression of Q&A. Rennet is an enzyme from a calf's stomach, it helps speed up reactions. The reaction in question here is coagulation of milk, which they just performed.

Why did the balloon get bigger?

How did the gas form? (double replacement reaction)

Why did the gas make the balloon get bigger?

What are other examples of pressure in the world?

Do you think pressure could cause pain?

- These questions show a progression of Q&A. The take home point should be lactose fermentation produced gas, which causes pressure in the intestine, which in turn can cause discomfort/pain

LESSON RESOURCES
ASSESSMENT GUIDE

Lesson 1 – What's Milk Made Of?

Summative Assessment Rubric – Milk Sketch

Milk sketch will be worth **10 points total.** Please encourage students to use their first milk sketch as a base/inspiration and to draw a new one given the new things they have learned. ***Please refer to the Lesson 1 documents and milk sketch handout for further instructions.***

Criteria	Unsatisfactory	Satisfactory	Outstanding	Score
Milk components types	Only included one major milk components. E.g., Milkfat globules OR Casein micelles OR Whey Protein OR Water OR Lactose **Points: 1**	Included 2-3 milk components. E.g., Milkfat globules OR Casein micelles OR Whey Protein OR Water OR Lactose **Points: 2-3**	Included all major milk components. E.g., Milkfat globules AND Casein micelles AND Whey Protein AND Water AND Lactose **Points: 4**	
Milk components scale	Drew at least two components to scale according to the following hierarchy: Milkfat globules > Casein Micelles > Whey Protein > Lactose > Minerals **Points: 1**	Drew at least three components to scale according to the following hierarchy: Milkfat globules > Casein Micelles > Whey Protein > Lactose > Minerals **Points: 2**	Drew all components to scale according to the following hierarchy: Milkfat globules > Casein Micelles > Whey Protein > Lactose > Minerals **Points: 3**	
Milk components labelled	Labelled at least two major milk components. E.g., Milkfat globules OR Casein micelles OR Whey Protein OR Water OR Lactose **Points: 1**	Labelled at three two major milk components. E.g., Milkfat globules OR Casein micelles OR Whey Protein OR Water OR Lactose **Points: 2**	Labelled all the major milk components. E.g., Milkfat globules OR Casein micelles OR Whey Protein OR Water OR Lactose **Points: 3**	

LESSON RESOURCES

MILK SKETCH HANDOUT

NAME:_____

A glass of milk looks white at first glance, but what would happen if you could look even closer?

USE YOUR IMAGINATION AND BRAIN POWER TO DRAW WHAT SECRETS MILK MIGHT BE HIDING…

Make sure you label the parts of your drawing!

LESSON RESOURCES
ASSESSMENT GUIDE

Lesson 1 – What's Milk Made Of?

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LESSON RESOURCES

LACTOSE LAB HANDOUT

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