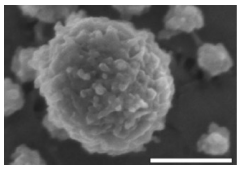
Chapter 3 Milk and Ice Cream



Electron micrograph of milk globule (above) and whipped cream (below)

Milk is a basic nutritional component for all animals providing nutrients and immune proteins.

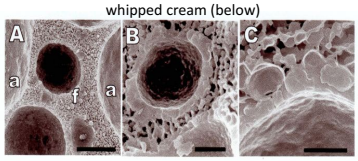


Figure 3-18 Electron Microscopy of Whipped Cream. A. Overview of (a) air and (f) fat globules. B. Internal structure of air bubble highlights the partially coalesced fat. C. Interaction of fat globules within the fat layer. Courtesy of Prof. Douglas Goff, University of Guelph, Canada

Milk and Dairy

WHAT IS MILK? U.S. Code of Federal Regulations, Title 21, Vol. 8, Chpt 1, Pt 1240, subpart A, Section 1240.3(j), Release 13

"the lacteal secretion obtained from one or more healthy milk-producing animals, e.g. cows, goats, sheep, and water buffalo, including, but not limited to, the following: lowfat milk, skim milk, cream, half and half, dry milk, nonfat dry milk, dry cream, condensed or concentrated milk products, cultured or acidified milk or milk products…"

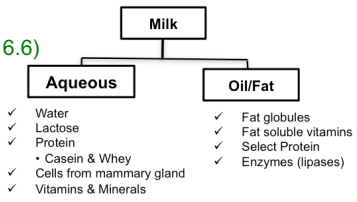
What is milk – No, Really?

An emulsion of fat goblets coated in protein suspended in protein-rich water – no really!

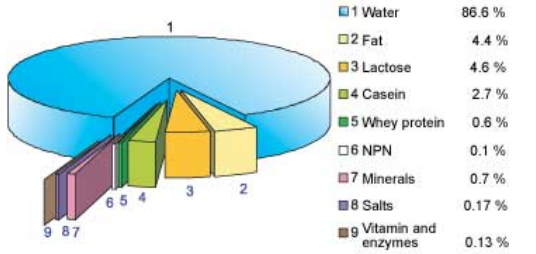
Composition of milk:

•Liquid phase:
- Lactose
- Slightly acidic water (pH 6.6)
- Bundles of proteins

•Fat phase:
- Droplets of oil cased in protein



What is milk? Mostly water!



NPN – Non-protein nitrogenous compounds

taken from MilkFacts.info

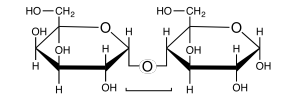
Species	Water	Fat	Casein	Whey	Lactose
Human	87.1	4.6	0.4	0.7	6.8
Cow	87.3	4.4	2.8	0.6	4.6
Buffalo	82.2	7.8	3.2	0.6	4.9
Goat	86.7	4.5	2.6	0.6	4.4
Sheep	82.0	7.6	3.9	0.7	4.8
Horse	88.8	1.6	1.3	1.2	6.2
Rat	79.0	10.3	6.4	2.0	2.6
Ass	88.3	1.5	1.0	1.0	7.4
Reindeer	66.7	18.0	8.6	1.5	2.8
Camel	86.5	4.0	2.7	0.9	5.4

Milk Sugars

Lactose provides nearly half of the calories from milk

- Made from two simple sugars

A disaccharide molecule of lactose (i.e. milk sugar)



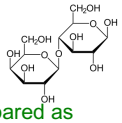
1-4 α glycosidic bond

This half of lactose is made of Galactose

This half of lactose is made of Glucose

What is milk – No, Really?

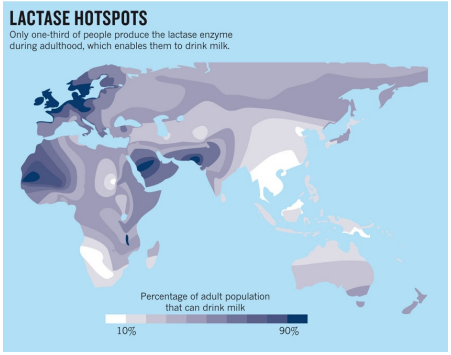
Composition of milk: Liquid phase:



- Lactose
  - Disaccharide - glucose and galactose prepared as separate molecules and condensed into "milk sugar" through the secretory cells
  - Ability to digest (metabolize or "break down") lactose requires a special enzyme – lactase
  - Lactase is produced in gut by children but levels decrease in adults.
  - Northern Europeans maintain levels but only 30% of others can produce significant quantities

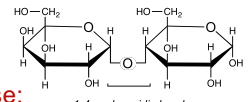
Lactose intolerance by group

What is the trend of locations of people with and without lactose intolerance?



What is milk – No, Really?

A disaccharide molecule of lactose (i.e. milk sugar)



1-4 α glycosidic bond

This half of lactose is made of Galactose

This half of lactose is made of Glucose

Composition of milk: Liquid phase:

•Lactose

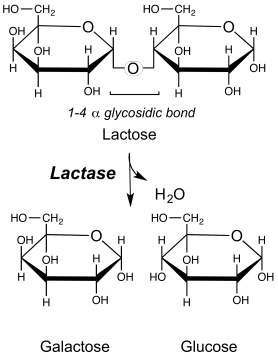
- If the sugar isn't hydrolyzed sugar is transported to the gut where two things happen
  - Water rushes into the intestine from the belly – osmosis
  - Bacteria will start to metabolize the sugar to $CO_{2(g)}$ and $CH_{4(g)}$
- Result – cramps, gas and diarrhea…diarrhea..

Called Lactose intolerance

- Enzymes mass produced in pill form can help

Actions of Lactase

The enzyme lactase hydrolyzes the glycosidic bond of lactose producing galactose and glucose – making available the monosaccharides for further metabolism



What is milk – No, Really?

Composition of milk: Liquid phase:

•Lactose

Why Lactose? Animals and Humans use glucose as main sugar source?

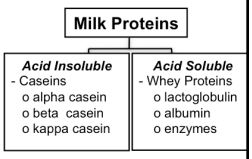
•Second half of lactose (galactose) is used for Neural tissue – important in early development of mammals

•Most bacteria can't digest lactose for 1-2 days/hrs providing a "safe time" for contamination free milk

What is milk – No, Really?

Composition of milk: Liquid phase:

•Proteins – Curds and Whey!



- 1000s of proteins divided by their stability in acid
  - Where does the acid come from? Hmmmmm?
- Unstable – proteins which denature in acidic solutions bind to each other – aggregation or coagulate
- These are Curds. When milk curdles, what is happening?

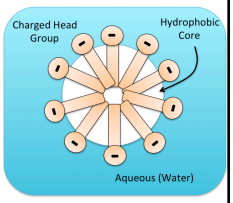
Curds and Whey

Cottage Cheese!

So what is a tuffet?

- An old word for a bushel of hay or straw

Casein



Major single protein produced in milk

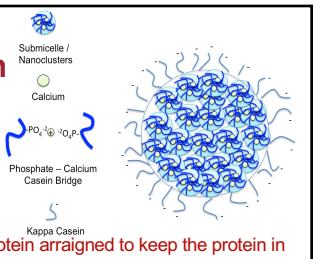
Key characteristics of casein

- Heat stable – well folded protein
- "floats" in micelle form (globs of protein arraigned to keep the protein in solution)

Milk Proteins

Acid Insoluble	*Acid Soluble*
- Caseins o alpha casein o beta casein o kappa casein	- Whey Proteins o lactoglobulin o albumin o enzymes

Casein



- Heat stable – well folded protein
- "floats" in micelle form (globs of protein arraigned to keep the protein in solution)
  - Hydrophobic portion of protein in mi
- Calcium binds tightly to this protein – helps to carry calcium into the blood system!
- Four main forms of Casein – one "caps" micelles limiting the size
- At acid levels above 4.5, proteins are neg charged and repel.
- When acid increases to pH lower than 4, proteins denature and are not charged – thus they bind to each other and "curdle"
- Body builders sometimes use this as a "slow-digesting protein" (why)

Whey

The other protein found in liquid phase of milk

- Stay in solution in acidic conditions
- Many of these proteins are immunoglobins (antibodies for the young animal)
- Lactoglobin has several sulfur atoms – provides flavor and odor to cooked milk
- Proteins in whey are used for animals as source of nutrition
- Under more extreme conditions than casein, whey proteins can form small clots – ricotta cheese
- These proteins help make ice cream… creamy

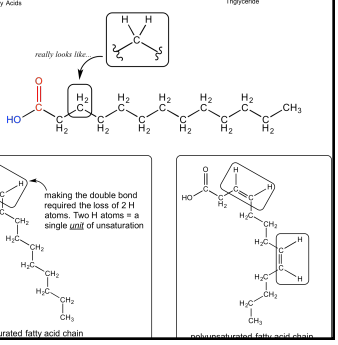
Milk Fat

The other phase of milk –

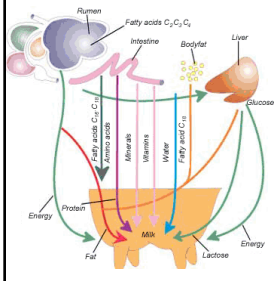
•The non-liquid part of milk is a globules of fat which are mixed with lots of different kinds of molecules

- Fats – the kinds of fats and amount of fat globules in milk vary as the types of food the cow eats, the season and temp of year and when the hormonal state of the cow
  - More fat in winter, and at end of lactation period
  - Mostly saturated fats and few polyunsaturated fats
- Fat soluble vitamins – A,D,E and K

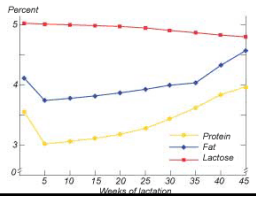
Milk contains about 65% saturated, 30% monounsaturated and 5% polyunsaturated fatty acids (either free fatty acids or fatty acids bound to glycerol).



Variations of Milk



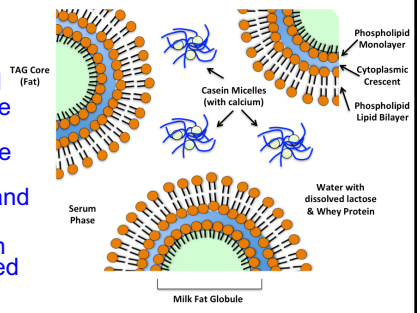
Breed	Fat %	Casein %	Whey %	Lactose%
Brown Swiss	3.8	2.63	0.55	0.72
Holstein	3.56	2.49	0.53	0.73
Jersey	4.97	3.02	0.69	0.77



Delaval.com

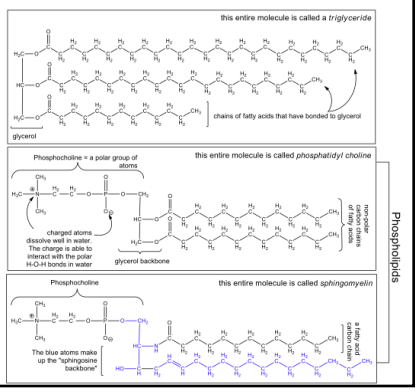
Structure of Milk

Fat globules with three layers of lipid membranes encase the triacylglycerol (TAG) fat core. The serum phase with dissolved lactose and whey proteins contains the casein micelles coordinated with calcium ions.



Milk Globules

Membranes – Phospholipids and sphingolipids



Fat Globules

The richness of milk, creams or cheeses refers to the fat content –

Fat globule – coated with protein and charged phospholipids (emulsifiers)

- Creates charged spheres that repel each other
- If globules were to contact, they would pool resulting in a big batch of oil.
- This formation protects by "hiding" the fat from bacteria which would quickly digest/eat the oil

Pasteurization and Homogenization

Heat + Time = Sterilization.

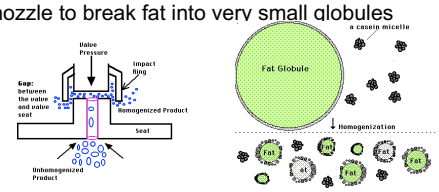
- Subject food to enough heat to kill contaminating pathogenic bacteria but not cook food (too much)
- This is the basis for pasteurization or any kind of food preparation.
- High Temp Short time vs low temp long time

Irradiation – exposure to small amounts of gamma rays – kills parasites but like cooking can alter food nutrient value

Pasteurization and Homogenization

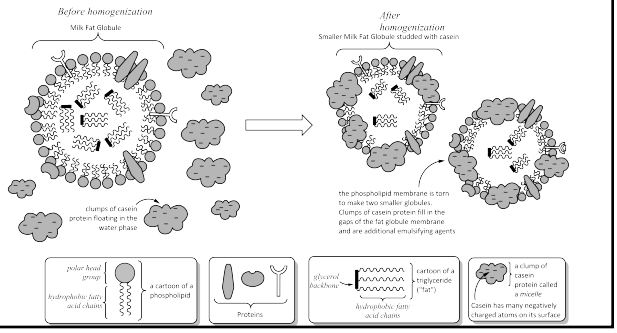
Homogenization

- Left alone, milk will separate – less dense large fat globules float and pool at top of more dense water layer
- Homogenization forces milk (while hot) through small nozzle to break fat into very small globules



Homogenization

- More, smaller fat globules result in higher surface area
- Not enough membrane to cover fat – so casein will coat the fat
- Smaller globes are less dense and repelled by casein

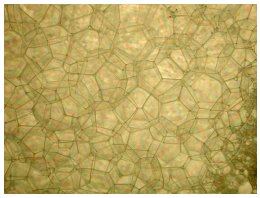


Common milks found in the market:

- Vitamin D or Whole Milk: Homogenized and pasteurized milk packaged with additional Vitamin D added. None of the fat has been removed prior to packaging (3.5% fat)
- Low fat or skim milk: Milk which some or nearly all of the milk fat has been removed. These milks range from 2% fat to less than 0.5% fat (non fat or skim milk). Because the body of the milk is more watery without the fat. These milks often are supplemented with whey protein.
- Condensed milk: sweetened or non-sweetened, whole milk with much of the water boiled away. This milk was created to serve as a concentrated form of milk and fight food poisoning during the U.S. Civil war in 1865. Now this is commonly used for a range of cooking and baking. Originally, sweetened condensed milk has added table sugar to limit bacterial growth.
- Whipping and heavy creams: Cream is the fat globule layer from milk which has creamed. Differences between heavy (30%) and whipping cream (36-40% fat) are primarily in the concentration of fat. Both creams can be used to make whipped cream, although the more fat the better the resulting foam. Half and half is a mixture of milk with cream for a lower percent fat (10-18%).

Milk Foam

Foam – a network of protein and or fat and sugar creating a cage around pockets of air.



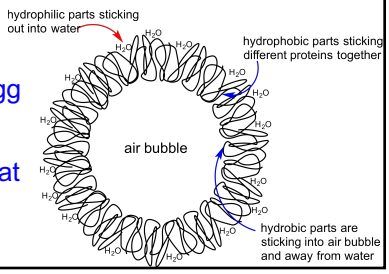
Foam

Espresso foams - milk foams made of coagulated whey proteins forming the cage around the bubbles in the steam

- Less protein than other foams and are thus unstable

Meringue foam – egg white protein and sugar foam

Whipped Cream – fat globule cages



Creams and Butter

Cream - Separated fat from raw milk

- what's left behind? Skimmed milk!

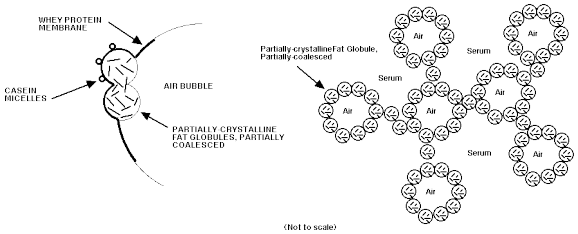
- Light and heavy whipping cream is about the fat content
- Creams used in cooking serve to keeping denatured proteins (like caseins) from binding to each other and clotting (aka curdling)
  - This happens because the globule membranes remain intact during cooking and bind to the proteins as they denature while cooking
  - Try cooking high fat vs low fat yogurt or cream with or without an emulsifier

Whip it good…

Whipping cream – keep it cool and don't over do your whipping!

- These foams are a thick stable cage of fat globules
- Formed when mechanically shearing the heavy cream – why heavy and not light?
- Whipping breaks the fat into smaller pieces which the membranes can't fully cover
- This results in partial connected (crystalline) globes of fat with proteins wrapped around air bubbles

Up close look at whipped cream



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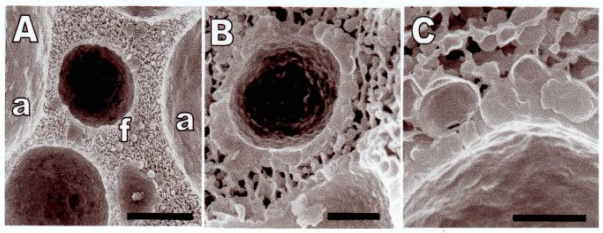
Up close look at whipped cream



The structure of whipped cream as determined by scanning electron microscopy. A. Overview showing the relative size and prevalence of air bubbles (a) and fat globules (f); bar = 30 um. B. Internal structure of the air bubble, showing the layer of partially coalesced fat which has stabilized the bubble; bar = 5 um. C. Details of the partially coalesced fat layer, showing the interaction of the individual fat globules. Bar = 3 um.

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Whip it good…

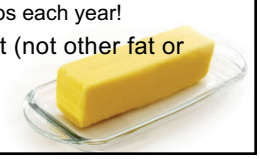
Whipping cream – keep it cool and don't over do your whipping!

- Warm fat – oozes together and pools into one big blob – no air, no foam
- Over whipped fat (while cold) forms too many contacting fat globs and the cream turns into … butter

Butter

What is butter?

- Churned Cream resulting in a hardened fat with ***most*** of the water expelled
- 21 lbs of fresh cow's milk are needed to make one pound of butter
- An avg American consumes >4 lbs each year!
- 80% of mass must be milkfat (not other fat or solids)



Fats in Butter

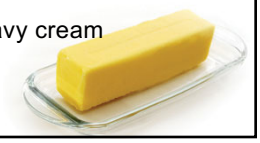
Fat Composition in Butter

Fatty acid	Structure	% total fatty acid in butter
oleic acid	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$	31.9
myristic acid	$CH_3(CH_2)_{12}COOH$	19.8
palmitic acid	$CH_3(CH_2)_{14}COOH$	15.2
stearic acid	$CH_3(CH_2)_{16}COOH$	14.9
lauric acid	$CH_3(CH_2)_{10}COOH$	5.8
butyric acid	$CH_3CH_2CH_2COOH$	2.9
caproic acid	$CH_3(CH_2)_4COOH$	1.9
capric acid	$CH_3(CH_2)_8COOH$	1.6
caprylic acid	$CH_3(CH_2)_6COOH$	0.8
linoleic acid	$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$	0.2
linolenic acid	$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7COOH$	0.1

Making Butter

Prepare the cream – heavy cream of whole milk

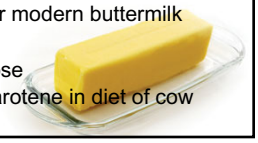
- Concentrate by heating cream or using whole un-homogenized milk
  - Let stand 6-12 hrs (cultured or not…)
  - Skim off cream.
- Alternatively start with heavy cream
  - The work is already done!



Making Butter

Churn!

- The high fat content is still stable in the fat globules
- Butter crystals or grains form to help break fat
- Churning simply provides mechanical breakage of the membranes of the fat globules
- Eventually the fat pools at room temps
- Buttermilk – old fashioned kind
- Add protein for and a bit of acid for modern buttermilk
- Solid is ready to use or finish
- Contains water fat and some lactose
- Yellow color comes from dye or carotene in diet of cow



Kinds of Butter

Salted Butter

- Add salt to final butter or soak in 2% salt water (brine)
- Salt reduces spoilage as the bacteria can not grow in high salt conditions

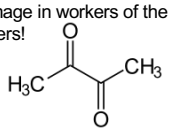
Sweet Cream Butter

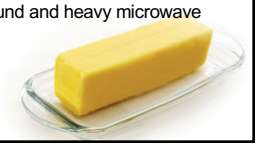
- No salt, butter formed after milk liquid is removed

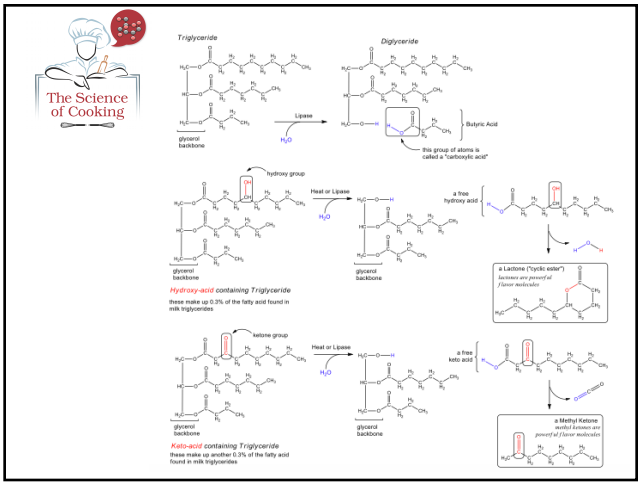
Kinds of Butter

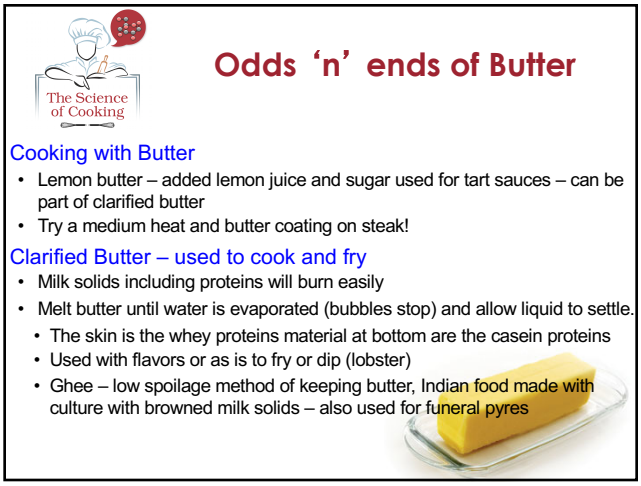
Cultured Butter

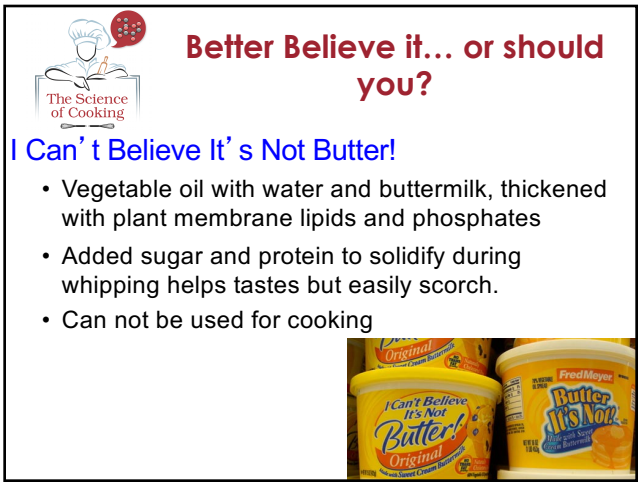
- Cream is cultured with bacteria and acidified
- Give the butter a different, sour taste
- One by-product is diacetyl – once used for artificial "butter taste"
  - I can't believe, microwave popcorn, even provided a butterscotch or slippery taste to alcohol…
  - Inhibits enzymes (arginine binding in superoxide dismutase) which are important for protecting cells from oxidative damage
  - Caused damage in workers of the compound and heavy microwave popcorn eaters!






The Science of Cooking
Triglyceride
Diglyceride
Lipase
Butyric Acid
glycerol backbone
hydroxy group
Heat or Lipase
a free hydroxy acid
a Lactone ("cyclic ester")
Hydroxy-acid containing Triglyceride
these make up 0.3% of the fatty acid found in milk triglycerides
ketone group
a free keto acid
a Methyl Ketone
Keto-acid containing Triglyceride
these make up another 0.3% of the fatty acid found in milk triglycerides


The Science of Cooking
Odds 'n' ends of Butter
Cooking with Butter
• Lemon butter – added lemon juice and sugar used for tart sauces – can be part of clarified butter
• Try a medium heat and butter coating on steak!
Clarified Butter – used to cook and fry
• Milk solids including proteins will burn easily
• Melt butter until water is evaporated (bubbles stop) and allow liquid to settle.
• The skin is the whey proteins material at bottom are the casein proteins
• Used with flavors or as is to fry or dip (lobster)
• Ghee – low spoilage method of keeping butter, Indian food made with culture with browned milk solids – also used for funeral pyres

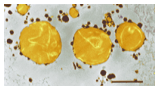

The Science of Cooking
Better Believe it… or should you?
I Can't Believe It's Not Butter!
• Vegetable oil with water and buttermilk, thickened with plant membrane lipids and phosphates
• Added sugar and protein to solidify during whipping helps tastes but easily scorch.
• Can not be used for cooking
I Can't Believe It's Not Butter!
Original
FredMeyer
Butter It's Not

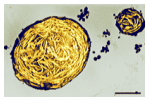

The Science of Cooking
Better Believe It… or should you?
Margarine
• Vegetable Margarine – partially hydrogenated vegetable oils
• Traditional Margarine – animal fat (tallow) flavored and mixed with milk
• Tallow is rendered animal fat – typically from beef.
• Hard fat found near kidney – high in saturated fat and thus works as a butter

I scream

Ice Cream is a result of chemical technology

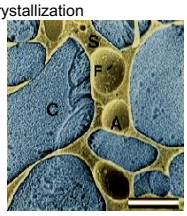
- Ice Cream is a mixture of ice (water and partially solid milk fat), liquid (cream and sugared water) and air pockets (1/2 of the volume).
- Differences are in the fat and protein which create a creaminess, the amount of crystals of fat and water and the protein emulsifiers which stabilize the membranes of the fat and decrease crystallization





Left - Microscope images of ice cream
Fat droplets (orange)
Proteins (black)
-notice the level of fat crystals shown in the lines in the lower image

Right- Electron M-scope images
Air Bubbles (A)
Ice Crystals (C)
Fat Globulets (F)
Un-frozen water, fat and sugar (S)



I scream

Ice Cream is a result of chemical technology

- More crystals (fat or water) lead to less smooth and more "crunchy" ice
- Whipping, emulsifiers and sugar all influence the crystals as they freeze
- To "ice the cream" all one has to do is create an environment colder than the freezing point of the water in milk
  - So the challenge is to create a lower temp than sugar water (less than 0°C)
  - BUT the temp of ice warmer (0°C) than the temp needed to freeze the cream
  - 13th Century Arabs knew how to create a colder than ice temp using salt

Freezing point depression

- A solution of water and solute (some other compound) will have a lower freezing point than pure water
- This is a result of ions interfering with the ability of water to form a latice (cage) of bonded molecules – ICE ICE BABY!

Formally looking at melting point

Colligative Property – *the freezing point is influenced and due to the small amount of dissolved solids (salt ions) rather than the solute (water molecules)*

$$\Delta T_f = K_f c_m$$

ΔT_f = is the change of temp
K_f = is a constant for the solvent (water)
c_m = is the concentration

So what? The more salt particles - the bigger the freezing point depression
- this is how frogs and other mammals can survive freezing

Taste of Ice Cream

Federal standards (**21 CFR § 135.110**) require ice cream to contain a minimum of 10% milk fat and 20% milk solids. Some premium ice creams contain 16% milk fat. -Ice cream contains not less than 1.6 pounds of total solids to the gallon, and weighs not less than 4.5 pounds to the gallon.

Overrun is a measure of the volume of air whipped into the ice cream mix. Overrun does not have to be declared on the label.

- Quality ice creams have lower overruns than those of reduced quality.
- Generally the more overrun, the lower the cost of the ice cream

Ice crystals form when some of ice cream's water separates from fat and eventually develops into larger ice crystals. The result is a grainy-textured ice cream. As long as water remains trapped in an emulsion with fat in ice cream, the original ice crystals do not get larger.

- To protect ice cream from developing large ice crystals, do not melt and refreeze ice cream, and do not store ice cream well below 0°F for a prolonged period.