SCIENCE OF Chocolate

AMERICAN HERITAGE® CHOCOLATE
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Tampa Bay Times NIE
newspaper in education
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THE CHOCOLATE ECOSYSTEM

AP Photo/Fernando Llano

Wikimedia Commons

Chocolate is made from the seeds of the cacao tree (*Theobroma cacao*, pronounced kah KOW), which is native to South and Central America.

Cacao trees grow only in hot, rainy tropical areas, within a band approximately 20 degrees north and south of the equator. Wild cacao trees thrive in the understory of rainforests, where a canopy of taller trees provides shade and protection from wind, and the decaying organic material of the forest floor supplies nitrogen and other nutrients.

The cacao tree is cauliflorous, which means that its flowers and fruits grow directly on the trunk and branches, not from new growth or shoots.

Cacao trees cannot pollinate themselves. Their flowers must be pollinated with pollen from a different cacao tree for the tree to produce fruit. Because the flowers are tiny (about a half inch in diameter), only very small insects can enter the cacao flower to transfer the pollen. The most important cacao pollinators are tiny flies called midges that live in the rainforest debris surrounding the tree.

The fruits of the cacao tree are pods about the size and shape of an American football. Each cacao pod contains 25-40 seeds surrounded by an edible white pulp. These seeds, or beans, are what is processed to make chocolate.

Cacao trees depend on animals such as monkeys, rodents and birds, to spread their seeds. These animals eat the sweet white pulp, but spit out the bitter-tasting seeds, dispersing them on the rainforest floor to produce new trees.

Sources: Britannica; The Field Museum, "Cocoa Connections: From Beans to Bars"; International Cocoa Organization; National Geographic; Scientific American

FOOD OF THE GODS

Carl von Linné (Linnaeus), who invented the system of classifying living things that we still use today, gave cacao the botanical name *Theobroma cacao* in 1741. "Theobroma" is from Greek and means "food of the gods."

Cacao ecosystem

An ecosystem is a biological community of interacting organisms and their physical environment. In other words, an ecosystem is an area where living and nonliving things interact to form a web of life.

Think about all the different parts of the cacao ecosystem listed below and how they interact. In small groups, write down as many ways the organisms are connected to each other as you can. (For example, the sun provides energy for the cacao seed to sprout and grow.)

- Sun
- Canopy trees
- Cacao pod
- Midges
- Birds
- Cacao seed
- Monkeys
- Cacao flower
- Leaf litter
- Humans

Next, imagine that one element is removed from the ecosystem. What is the effect of that one loss? How many parts of the web are affected by the loss? What might cause such a loss? Create a infographic showing how the elements interact and what happens when the ecosystem is disrupted. Share what you have learned with your class.

Adapted from: The Field Museum, "Cocoa Connections: From Beans to Bars"

Florida Standards: SS.8.G.5.2; SC.7.L.17.1; SC.7.L.17.3; SC.68.N.1.1; SS.6.G.3.1; SS.6.G.3.2

AP Photo/Fernando Llano

AP Photo/Fernando Llano

Digging deeper: Biodiversity in the news

The study of ecosystems goes hand-in-hand with biodiversity. Short for biological diversity, this refers to "the variety of all living things and their interactions," according to the Natural Museum of Natural History. "Biodiversity changes over time as extinction occurs and new species evolve." Biodiversity in ecosystems plays an important role on Earth. The World Health Organization notes that this variability among living organisms from all sources supports all life on Earth. This includes diversity within species, between species and across ecosystems. Healthy communities are sustained by well-functioning ecosystems, which provide critical services such as clean air, fresh water, natural medicines and food security. Read through the Tampa Bay Times and look for articles and photos that have examples of biodiverse ecosystems. Using the articles and images you have found, write a brief one-page essay analyzing the biodiversity and ecosystem depicted. Share your article, images and thoughts with your class.

Florida Standards: SC.7.L.17.3; SC.68.N.1.1; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.C.4.1; ELA.68.R.2.2

TIMELINE OF CHOCOLATE

3200 BCE (Before Common Era)
Archaeological evidence suggests cacao use by people living in what is now Ecuador.

1900 BCE
Archaeological evidence suggests cacao use by people living in what is now southern Mexico.

200-900 CE (Common Era)
The Maya are the first civilization to record the farming of cacao.

Maya chocolate pot, c. 750 CE, with the glyph for "cacao" in the ancient Maya language, confirming its ancient function as a chocolate pot. Minneapolis Institute of Art

Maya Glyph for cacao. Wikimedia Commons

Alkalization, also known as Dutch processing or Dutching, is an optional process that mellows the flavor and modifies the color of cocoa. The process consists of mixing the cocoa with an alkaline solution that neutralizes cocoa's natural acidity of between 5 and 6 pH to a pH of 7, the same as water. Common alkaline compounds used include potassium carbonate, calcium carbonate and sodium hydroxide.

Sources: Compound Interest (compoundchem.com); The Field Museum, "Cocoa Connections: From Beans to Bars"; International Cocoa Organization; Royal Canadian Institute for Science (RCIScience); scienceofcooking.com; Serious Eats

HOW CACAO BECOMES CHOCOLATE

1 HARVEST

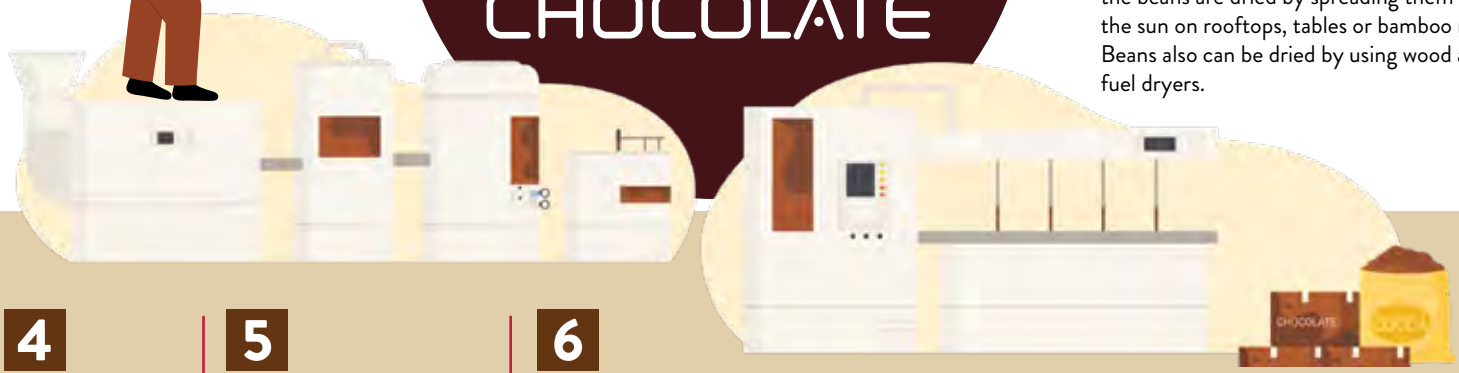
Because cacao pods grow directly off the trunk and branches of the tree, they must be harvested by hand. Farmers use a machete or similar tool to slice the pods from the tree. The pods are then split open and the pulp-covered beans removed. The beans are piled together and covered to initiate fermentation, a chemical process by which molecules are broken down without oxygen, of the pulp. Alternatively, the fruit can be eaten or squeezed for juice!

2 FERMENT

The fermentation process lasts 2-5 days, depending on the type of bean. During fermentation, yeasts and other microorganisms cause complex chemical changes to take place in the beans. These chemical reactions cause the chocolate flavor and color to develop.

3 DRY

After fermentation, the beans are dried to reduce their moisture content. Traditionally, the beans are dried by spreading them in the sun on rooftops, tables or bamboo mats. Beans also can be dried by using wood and fuel dryers.



4 ROAST

In the first step in making chocolate, dried cacao beans are roasted and begin to smell like chocolate.

5 WINNOW

Next, the husks, or shells, are removed, leaving the chocolate "nib," in a process called winnowing. The nibs can then be processed into what we recognize as chocolate.

Cacao husks can be used to make tea, as animal fodder or as fertilizer. In fact, First Lady Martha Washington was known to enjoy a tea-like chocolate beverage made from steeping cacao shells in hot water.

6 GRIND

The cacao nibs are ground until they have been reduced to a thick paste. This paste, called "chocolate liquor," contains cocoa solids and cocoa butter (no alcohol involved.).

7 CONCH

Conching is a mixing and heating treatment that is conducted to improve both the flavor and the texture of the chocolate. Chocolate makers combine the chocolate liquor with sugar and cocoa butter (and, for milk chocolate, milk or milk powder) in different ratios to make various chocolate products.

Alternatively, the chocolate liquor can be pressed to create pure cocoa butter and pure cocoa powder. The liquor is heated to 200° C (392° F) and pumped into a horizontal hydraulic press, which presses the cocoa butter out from the liquor, leaving only the cocoa solids. The cocoa cake formed from this pressing operation is then cooled, broken and milled into cocoa powder.

8 TEMPER

The final process in making chocolate is called tempering. Tempering involves raising and lowering the temperature of the chocolate repeatedly in order to produce a shiny finish and "snap" when a chocolate bar is broken.

1502
Italian explorer Christopher Columbus, on his fourth voyage to the New World, meets a Mayan trading party with a canoe filled with cacao beans, which he mistakes for almonds.

1519
Spanish conquistador Hernán Cortés enters the Aztec capital and shares ceremonial cacao drinks with Aztec emperor Montezuma II.

Hernán Cortés. Florida Memory, State Archives of Florida

1544
Dominican friars bring a delegation of Maya nobles to visit Prince Philip in Spain, marking the first documented appearance of cacao in the Old World.

1579
English pirates burn a shipload of cacao beans, mistaking them for sheep droppings.

An Aztec woman pours chocolate from one vessel to another in the Codex Tudela, a 16th-century manuscript. Wikimedia Commons

1585
The first documented commercial shipment of cacao beans arrives in Spain from the New World.

1591
Pope Gregory XIII, the head of the Catholic Church in Rome, Italy, declares that Catholics could drink chocolate during the holy season of Lent without breaking their fast.

Fermentation in a bag

Fermentation is the chemical breakdown of a substance by bacteria, yeasts or other microorganisms. Fermentation typically produces effervescence, or froth, and heat. Fermentation is used to produce foods such as bread, yogurt, wine, cheese and kombucha.

In this experiment, students investigate the process of fermentation in resealable bags with baker's yeast, warm water and various sugars.

Materials

- Dry active yeast (one 4 ounce jar contains approximately 36 teaspoons of yeast, which will make 36 bags)
- Feedstock(s): sugar, cornmeal, corn stover, sawdust, switchgrass etc.
- Warm water source
- Measuring cups or small graduated cylinders
- Measuring spoons (one teaspoon for each feedstock source and the yeast to avoid cross-contamination)
- Resealable zipper bags ("snack" size)
- Rulers to measure bag inflation and/or classroom-grade ethanol probe (Vernier or PASCO) and/or breathalyzer for detecting ethanol levels

Procedure

1. Choose a sugar, starch or cellulose source for your yeast from the options provided.
2. Before you start, write down the food source you chose and what changes, if any, you expect to observe.
3. In the resealable bag, combine 1 teaspoon of your food source and 1 teaspoon of yeast.
4. Add 50 mL (1/4 cup) of warm tap water (approximately 40° C/100° F) and seal the bag, removing as much air as possible.
5. Mix gently. Lay the bag on a flat surface and watch for changes.**
6. Take measurements and record your observations for 10-30 minutes.
7. After the experiment, summarize what you know about substances in the bag before and after the experiment. What might explain the changes you observed? Compare your results with the other students in the class. What differences did you observe between food sources made of sugar, starch or cellulose? What might explain those differences?

Start time:_____ End time:_____ Total time (minutes):_____

Observations & Measurements	Before	After
Record scientific observations and measurements (changes in appearance, smell, size of bag, etc.)		

Questions	Start of experiment	After experiment
What's in the bag?		
What evidence do you have?		

***Warning: As the yeast produces carbon dioxide, the bag will expand – it may even pop! Be sure to monitor the bag and release the gas if it becomes too inflated.*

Adapted from: Great Lakes Bioenergy Research Center, "Fermentation in a Bag"
Florida Standards: SC.68.N.1.1; SC.68.N.1.3; SC.7.N.1.4; SC.6.N.1.5; MA.67.AR.3.5

Chemistry in action

While most people associate chemistry with school, chemistry is all around us. According to the American Chemical Society, "Everything you hear, see, smell, taste, and touch involves chemistry and chemicals (matter)." Breathing, moving and eating rely on chemical reactions. Look around the classroom or your house. If you took away everything that has been invented or improved through chemistry, you would probably be sitting outside on the dirt, without clothes.

Look up the definitions for "organic" and "synthetic," paying particular attention to definitions that apply to the field of chemistry. Next, look up the definition of organic chemistry. As a class, discuss the differences and similarities between organic and synthetic products or compounds.

Look through the sections of the Tampa Bay Times, including the sales flyers, to find examples of both organic and synthetic chemistry. Look for examples of products that have been produced or affected by chemistry. Create a chart categorizing these items. Remember, to include the physical newspaper. Finally, create a PowerPoint or Canva presentation for your class explaining what you have learned and seen in the newspaper.

Florida Standards: SC.68.N.1.1; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.C.4.1; ELA.68.R.2.2

1615 Chocolate enters France at the wedding of Louis XIII and Anne of Austria.

1635 Spanish friars are the first Europeans to successfully cultivate cacao trees, in Ecuador.

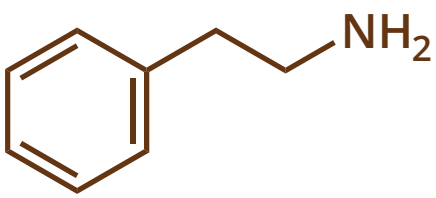
1641 The Spanish ship *Nuestra Señora del Rosario y el Carmen*, severely damaged in a hurricane while navigating the Florida Straits, is forced to make port in St. Augustine. The ship is carrying cacao beans, chocolate, and tools and utensils for making and serving chocolate. This marks the earliest record of chocolate in what would become the United States.

Aerial view of Castillo San Marcos in St. Augustine. Florida Memory, State Archives of Florida

1657 The first "chocolate house," named The Coffee Mill and Tobacco Roll, opens in London.

1659 The first French chocolate shop opens in Paris.

1670 A public house in Boston starts selling chocolate produced in Europe.



PHENYLETHYLAMINE

CHEMISTRY OF CHOCOLATE

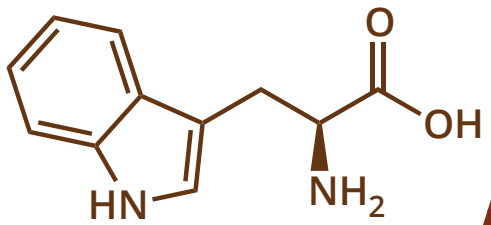
Cacao beans contain more than 400 chemical compounds, including different types of proteins, carbohydrates, minerals and fats.

More than half the weight of a cacao bean is cocoa butter, a mixture of different saturated and unsaturated fats. Cocoa butter gives chocolate its smooth texture.

Some of the other chemical compounds in cacao beans include:

Flavonoids are a group of plant compounds with antioxidant properties. The flavonoids in chocolate contribute to its taste and aroma.

Alkaloids are naturally occurring organic compounds that function to protect plants from attack by herbivores due to their bitterness. Two alkaloids found in the cacao bean are theobromine and caffeine.



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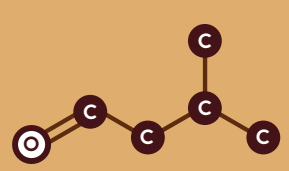
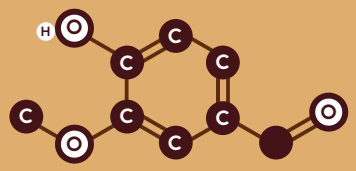
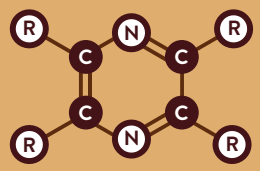


3-METHYLBUTANAL



VANILLIN



PYRAZINES

CHOCOLATE AROMA

The aroma, or smell, of chocolate is *almost* (but not quite) as good as its taste!

What we smell as "chocolate" is largely due to the chemical reactions that happen during the fermentation and roasting steps in the chocolate-making process.

Foods that are processed by fermentation, roasting or grilling usually contain the most aroma molecules: Think cheese, coffee and steak.

One of the most important chemical processes for aroma is the Maillard reaction.

The Maillard reaction occurs when proteins and sugars in and on your food are transformed by heat, producing new flavors, aromas and colors. Toasted bread, dark-roast coffee and seared meat all owe their flavor and aroma to the Maillard reaction.

In the case of chocolate, fermentation creates what are called "precursor chemicals" that are then transformed into aroma by the Maillard reaction during the roasting process.

Some of the chemicals that contribute to chocolate's sweet smell are:

- **3-Methylbutanal** – contributes a malty aroma
- **Vanillin** – contributes an aroma of vanilla. (Vanillin is not found in cocoa beans, but is often added to chocolate products.)
- **Pyrazines** – contribute nutty, cocoa and earthy aromas.

Sources: Compound Interest (compoundchem.com); The Field Museum, "Cocoa Connections: From Beans to Bars"; International Cocoa Organization; Scientific American; scienceofcooking.com; Serious Eats

DID YOU KNOW?

The word chocolate is derived from the Aztec "xocoatl," or "bitter drink." The bitter taste of unprocessed cacao and dark chocolate is due to alkaloids.

Cocoa powder is **hydrophobic**, which means that it repels water.

Test it.

Sprinkle dry cocoa powder over a bowl of water and try to poke your finger through. The cocoa resists sinking because it is hydrophobic. Then, stir it vigorously. By doing this, you are able to break the surface tension and create a mixture.

Compare it.

To see an example of a material that is **hydrophilic**, which means that it attracts or absorbs water, perform the same experiment with salt or sugar.

Source: Hersheyland.com

Price Currant at *Boston*.

Pitch,	11 s per Hundred.
Tar,	21 s per Barrel.
Turpentine,	12 s per Hundred.
Train Oyl,	35 Pound per Ton, and falling.
Fifh Merchantable,	23 l 6 d. per Quintal.
Dito Jamaica,	18 s. per Quintal.
Dito Barbadoes,	15 s. per Quintal.
Barbadoes Rum,	5 s. per Gallon.
Molaffes,	2 s. 4 d. per Gallon.
Cocoa,	7. Pound per Hundred.
Beaver Skins,	3 l. 10 d. per Pound.
Buck and Doe Skins in Oyl,	8 s. 6 d. per Pound.
Dito Indian Dreft,	5 s. per Pound.
Ditto in the Hair,	3 s. 8 d. per Pound.
Pine Boards,	55 s. per Thouſand.
Flower,	28 s. per Hundred.
Bread Courſe,	25 s. per Hundred.
Wheat,	7 s. 6 d. per Buſhel.
Indian Corn,	4 s. per Buſhel.

The American Weekly Mercury, Feb. 23, 1720

1682 Boston merchants start to import cocoa beans, marking the advent of chocolate production in the American colonies.

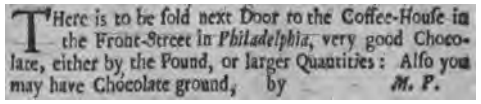
1687 A Jesuit missionary establishes a mission in Pimeria Alta, in today's Arizona, and offers gifts of chocolate to local Native Americans.

1690 An expedition searching for the first Spanish mission, San Pedro Creek in eastern Texas, records having chocolate among their food supplies.

1695 Settlers traveling to Santa Fe record having chocolate among their food supplies.

1712 Jesuit missionaries in the Sonora and Sinaloa regions of Mexico order chocolate and spices to prepare the chocolate drink.

1728 Englishman Walter Churchman develops a water engine to power his chocolate mill in Bristol, England.



There is to be ſold next Door to the Coffee-Houſe in the Front-Street in *Philadelphia*, very good Chocolate, either by the Pound, or larger Quantities: Alſo you may have Chocolate ground, by *M. P.*

The American Weekly Mercury, Dec. 13, 1720

GOING BEYOND THE TEXT

The importance of aroma

Aroma molecules are volatile, which means they transform into gases easily at room temperature. These volatile compounds are inhaled along with the air we breathe, bringing them into contact with the receptors in our noses.

Materials

- Bar of chocolate
- Table salt
- Colored plate
- Nose clip (optional)

Procedure

1. Place the unwrapped chocolate bar on a colored plate. Shake out some table salt next to it.
2. Put on the nose clip or **tightly** hold your nose so that no air can pass.
3. Take a piece of chocolate and chew it without swallowing. Note the lack of flavor.
4. Continue holding your nose. Take a pinch of salt and put some crystals on your tongue, still without swallowing. You should taste the salt, but not the chocolate.
5. Release your nose to get the chocolate flavor.

Source: "The Science of Chocolate" by Stephen T. Beckett
Florida Standards: SC.68.N.1.1; SC.68.N.1.3; SC.7.N.1.4; SC.6.N.1.5

Viscosity and flavor

Viscosity is a measure of how thick a fluid is. The greater the viscosity, the thicker the fluid. Therefore, honey is very viscous, while water is not at all.

The speed at which a food melts in your mouth (becomes liquid) affects its taste and its texture. This is because its viscosity affects the speeds at which the different molecules reach the flavor receptors on your tongue.

Materials

- Bars of chocolate (2)
- Refrigerator or freezer
- Butter knife
- Spoons
- Containers of yogurt (2)

Procedure

1. Use the knife to scrape shavings from one bar of chocolate. Place that bar and half of the shavings in a refrigerator or freezer for 24 hours.
2. Keep the other half of the shavings and the other bar of chocolate at room temperature.
3. After 24 hours, taste all four samples. Record each sample's hardness, speed of melt, creaminess and cocoa intensity. Although all were originally the same, large differences should be noticed.
4. Open both yogurts. Stir one container of yogurt vigorously so that it becomes a thin liquid. Taste both samples. What differences do you observe?

Source: "The Science of Chocolate" by Stephen T. Beckett
Florida Standards: SC.68.N.1.1; SC.68.N.1.3; SC.7.N.1.4; SC.6.N.1.5

Exploring scientific reactions

The Maillard reaction, named after French physicist and chemist Louis Camille Maillard, is often defined as "nonenzymatic browning reaction." This means that a chemical reaction occurs between amino acids and reducing sugars when foods are processed or cooked at high temperature. This reaction results in different aromas, flavors and brown colors.

Read the article "What is the Maillard Reaction?" on the following website: scienceofcooking.com/maillard_reaction.htm.

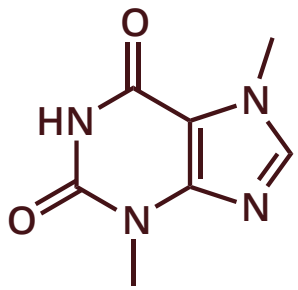
Next, look through the Tampa Bay Times to find examples – articles, photos, advertisements or cartoons – of food items that use the Maillard reaction. Using these articles and the information from the article, write a blog post explaining the reaction. Be sure to use the specific examples you have found in the newspaper to show how this reaction is used in products used in our day-to-day lives. Share what you have learned with your class.

Sources: "Food Processing and Maillard Reaction Products: Effect on Human Health and Nutrition" by Nahid Tamann; scienceofcooking.com
Florida Standards: SC.68.N.1.1; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.C.4.1; ELA.68.R.2.2

Why is chocolate toxic to dogs and cats?

Chocolate contains theobromine, a mild stimulant similar in effect to caffeine. This compound is harmless to humans at the levels found in chocolate. However, theobromine has a much more potent effect in cats and dogs. Even small doses can lead to severe stomach upset, and less than 2 ounces of dark chocolate could kill a small dog.

Source: Compound Interest (compoundchem.com)



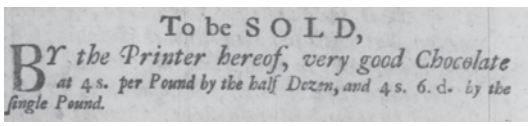
THEOBROMINE

Watch a video about Chocolate in George Washington's America from George Washington's Mount Vernon at youtube.com/watch?v=tobbVlBmQzI

George Washington. GiorgioMorara, stock.adobe.com

1735
Benjamin Franklin sells chocolate out of his print shop in Philadelphia.

1737
A hand-operated chocolate machine is advertised for sale in a Boston newspaper.


To be SOLD,
BY the Printer hereof, very good Chocolate at 4s. per Pound by the half Dezen, and 4s. 6. d. by the single Pound.

The Pennsylvania Gazette, May 15, 1735

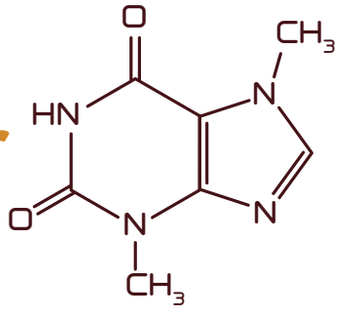
1741
Carl von Linné (Linnaeus), who invented the system of classifying living things that we still use today, gives cacao the botanical name *Theobroma cacao*. "Theobroma" is from Greek and means "food of the gods."

1755
During the French and Indian War, Benjamin Franklin procures chocolate for the British soldiers fighting the French.

1758
George Washington orders 20 pounds of chocolate and 20 pounds of cacao bean shells. He continues to order and enjoy chocolate for the rest of his life. Three months before his death in 1799, Washington orders 50 pounds of chocolate.

PHYSICS OF CHOCOLATE

Chocolate on a molecular level

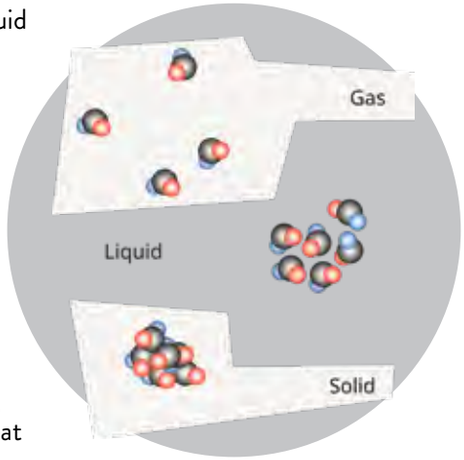


The three states of matter – gases, liquids and solids – are all made up of microscopic particles, but the behaviors of these particles differ in the three states.

In a gas, particles are spaced out and move freely past each other. In a liquid, particles are close together, but move past each other easily. In a solid, the particles are tightly packed, usually in a regular pattern. This pattern, or structure, gives the solid unique properties.

Chocolate is an interesting substance because it is solid at room temperature and liquid at body temperature.

Even more interesting, chocolate is *polymorphic*. Polymorphism is the ability of a chemical compound to stack its particles together in different ways. In fact, chocolate has six different structures, or crystal forms, each with different properties. Type I chocolate has the lowest melting point, and Type 6 has the highest. The process of tempering allows chocolate makers to control what type they produce.



Sources: Compound Interest (compoundchem.com); The Field Museum, "Cocoa Connections: From Beans to Bars"; International Cocoa Organization; Royal Canadian Institute for Science (RCIScience); scienceofcooking.com; Serious Eats

THE SIX TYPES OF CHOCOLATE

TYPE	MELTING POINT	DESCRIPTION AND PROPERTIES
1	17.3°C	Soft and crumbly with noticeable blooming (Blooming is the whitish coating that can appear on the surface of chocolate.). Type 1 is produced by cooling melted chocolate rapidly (e.g. by putting it in the freezer).
2	23.3°C	Soft and crumbly with noticeable blooming. Type 2 is produced by cooling melted chocolate at 2°C per minute. Type 1 crystals also gradually become type 2 after a short time of freezing temperature storage.
3	25.5°C	Firm, but doesn't give a good snap, some blooming. Type 3 is produced by cooling at 5-10°C. Type 2 becomes type 3 after storage at low temperatures above freezing.
4	27.3°C	Firm, but doesn't give a good snap, some blooming. Type 4 is produced by allowing melted chocolate to cool at room temperature. Type 3 also becomes type 4 after storage at room temperature for some time.
5	33.8°C	Shiny, smooth texture, good snap and melts in the mouth. Type 5 is formed by tempering chocolate slowly at room temperature.
6	36.3°C	Hard and melts slowly in the mouth, some blooming. Type 6 cannot be formed from melted chocolate. It can only be formed after solid, tempered chocolate has rested for at least four months.

Source: Compound Interest (compoundchem.com)

1764

Dr. James Baker provides the financial backing for John Hannon, an Irish chocolatier, to begin grinding cacao beans and making chocolate in a grist mill on the Neponset River outside Boston.

After Hannon's death in 1779, Baker buys out Hannon's heirs and changes the name of the company to Baker's Chocolate, which still exists today as a subsidiary of Kraft Heinz.

St. Louis Post Dispatch, Jan. 2, 1900

1770

James Watt perfects the steam-powered engine, which will dramatically increase the production of chocolate.

Marie-Antoinette brings her personal chocolate-maker with her to the Court. He is given the official title of "Chocolate Maker to the Queen."

Marie-Antoinette. MariePascale, stock.adobe.com

1776

The French pastry chef Doret invents a hydraulic machine to grind cacao seeds and mix them with sugar.

The structure and properties of chocolate

The structure of a substance affects its properties, and this is also true for chocolate. In this experiment, students explore what happens to chocolate when it is melted and allowed to reharden, testing the taste and texture of the chocolate to determine how these properties have changed as a result of the change in structure.

Taste test

Materials

- Milk chocolate, 1 square per student
- Milk chocolate that has been melted and rehardened* (same type as above), 1 square per student

Procedure

1. Give each student 1 square of milk chocolate and 1 square of milk chocolate that has been melted and rehardened.
2. Visually examine the two pieces of chocolate. Do the two pieces of chocolate look different? Describe any differences.
3. Break each piece of chocolate in half. How would you describe the sound of each piece breaking? How easy or hard was it to break each piece of chocolate?
4. Eat the two pieces of chocolate. Do the two pieces taste different? Do they feel different on your tongue?
5. As a class, compare your results with the table of chocolate types. What type(s) of chocolate do you think you created?

Property	Milk chocolate	Pre-melted milk chocolate
Appearance		
Sound		
Difficulty to break		
Taste		
Texture		

* To prepare pre-melted chocolate: Use whole milk chocolate bars that are fully wrapped in one sealed wrapper. Place the bars somewhere warm, such as in the sun, to melt. Once melted, put into a refrigerator to harden quickly. Once set, remove from the refrigerator and store at room temperature.

Source: "The structure and properties of chocolate," Practical Chemistry project, Nuffield Foundation and the Royal Society of Chemistry

Florida Standards: SC.68.N.1.1; SC.68.N.1.3; SC.7.N.1.4; SC.6.N.1.; SC.8.P.8.1; SC.8.P.8.4

Exploring science

The secret to problem-solving is using the scientific method: a step-by-step plan to figure out life's questions — big and small. Modern day chocolate is a great example of how the scientific method has been used to revise and improve a product.

The scientific method is a process that scientists use to answer questions about the natural world. The steps of the scientific method are as follows:

1. Ask a question.
2. Do background research.
3. Form a hypothesis (a possible explanation that can be tested).
4. Test the hypothesis with an experiment.
5. Analyze the results of the experiment.
6. Draw a conclusion.
7. Communicate the results.

Besides scientists, who else uses the scientific method to solve problems? To investigate this idea, get into small groups, look through the Tampa Bay Times, and make a list of careers and jobs you read about. Beside each one, write how a person with that job might use the scientific method to solve problems at work. For example, a food critic may use the scientific method to write a review, while a law enforcement official may use the scientific method to solve a crime. Discuss these points within your group.

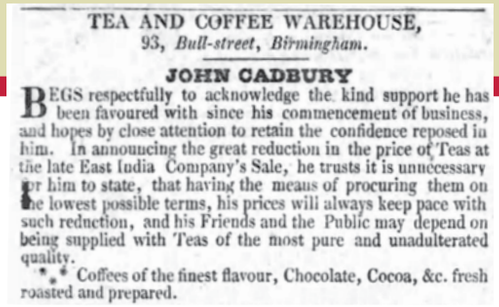
Choose one of the jobs or careers to explore further to describe how an employee would use the scientific method to complete tasks. Write up a brief report to share with your class.

Florida Standards: SC.68.N.1.1; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.C.4.1; ELA.68.R.2.2

Fry and Sons cocoa tin. National Museum of American History

1806

During the Lewis and Clark Expedition, William Clark writes in his journal: "*I felt my Self very unwell and derected (directed) a little Chocolate which Mr. McClellen gave us, prepared of which I drank about a pint and found great relief.*"



TEA AND COFFEE WAREHOUSE,
93, *Bull-street*, *Birmingham*.

JOHN CADBURY

BEGS respectfully to acknowledge the kind support he has been favoured with since his commencement of business, and hopes by close attention to retain the confidence reposed in him. In announcing the great reduction in the price of Teas at the late East India Company's Sale, he trusts it is unnecessary for him to state, that having the means of procuring them on the lowest possible terms, his prices will always keep pace with such reduction, and his Friends and the Public may depend on being supplied with Teas of the most pure and unadulterated quality.

*** Coffees of the finest flavour, Chocolate, Cocoa, &c. fresh roasted and prepared.

The Birmingham Journal, April 15, 1826

1824

John Cadbury opens a coffee and tea shop in Birmingham, UK, and sells chocolate.

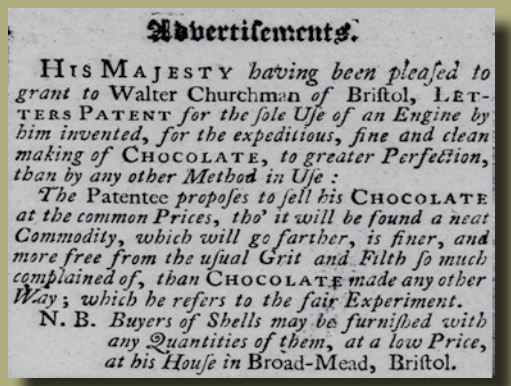
1828

Dutch chemist Coenraad Johannes Van Houten patents a process to separate cocoa butter from cocoa solids, resulting in what is now called "cocoa powder." The cocoa press expresses the cocoa butter out of the chocolate liquor produced by the grinding process, producing cocoa solids and cocoa butter.

1847

Joseph S. Fry and Sons, an English confectionary company, develops the first solid chocolate bar by blending together cocoa solids, cocoa butter and sugar. The resulting bar was coarse and gritty, but proved very popular.

History of chocolate manufacturing



Advertisements.

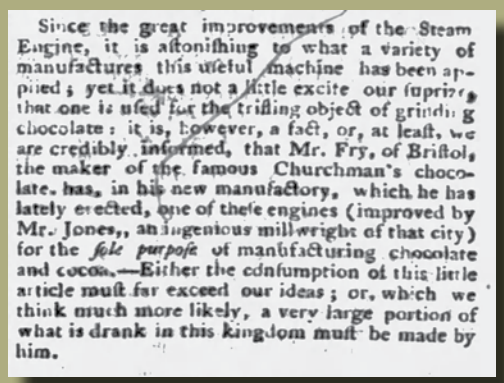
HIS MAJESTY *having been pleased to grant to* Walter Churchman *of* Briſtol, LETTERS PATENT *for the ſole Uſe of an Engine by him invented, for the expeditious, fine and clean making of* CHOCOLATE, *to greater Perfection, than by any other Method in Uſe:*

The Patentee *propoſes to ſell his* CHOCOLATE *at the common Prices, tho' it will be found a neat Commodity, which will go farther, is finer, and more free from the uſual Grit and Filth ſo much complained of, than* CHOCOLATE *made any other Way; which he refers to the fair Experiment.*

N. B. *Buyers of Shells may be furniſhed with any Quantities of them, at a low Price, at his Houſe in* Broad-Mead, Briſtol.

His Majesty having been pleased to grant to Walter Churchman of Bristol, LETTERS PATENT for the sole use of an Engine by him invented, for the expeditious, fine and clean making of CHOCOLATE, to greater Perfection, than by any other Method in use.

– The Gloucester Journal, July 13, 1731



Since the great improvements of the Steam Engine, it is aſtoniſhing to what a variety of manufactures this uſeful machine has been applied; yet it does not a little excite our ſurprize, that one is uſed for the trifling object of grinding chocolate: it is, however, a fact, or, at least, we are credibly informed, that Mr. Fry, of Briſtol, the maker of the famous Churchman's chocolate, has, in his new manufactory, which he has lately erected, one of theſe engines (improved by Mr. Jones,, an ingenious millwright of that city) for the *ſole purpoſe* of manufacturing chocolate and cocoa.—Either the conſumption of this little article muſt far exceed our ideas; or, which we think much more likely, a very large portion of what is drank in this kingdom muſt be made by him.

Since the great improvements of the Steam Engine, it is astonishing to what a variety of manufactures this useful machine has been applied; yet it does not a little excite our surprise that one is used for the trifling object of grinding chocolate: it is, however, a fact, or, at least, we are credibly informed, that **Mr. Fry, of Bristol, the maker of the famous Churchman's chocolate, has, in his new manufactory, which he has lately erected, one of these engines (improved by Mr. Jones, an ingenious millwright of that city) for the *sole purpose* of manufacturing chocolate and cocoa.** Either the consumption of this little article must far exceed our ideas; or, which we think much more likely, a very large portion of what is drank in this kingdom must be made by him.

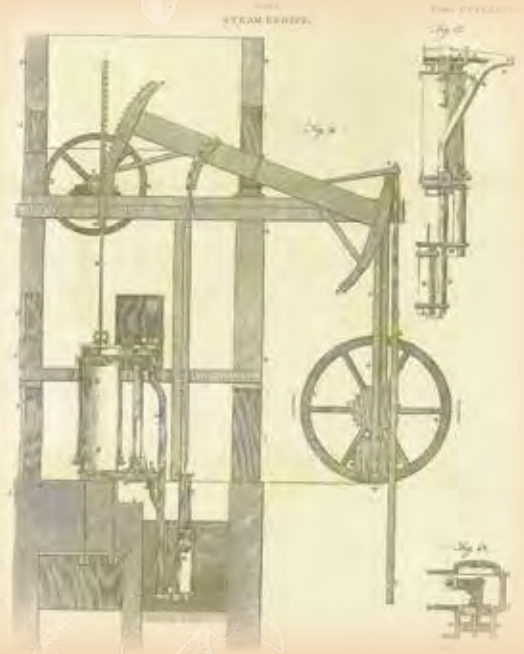
– Leicester Journal and Midland Counties General Advertiser, June 8, 1798

The ancient Olmec people of Mesoamerica, a historic region that included parts of Mexico and Central America, are thought to have been the first to domesticate the cacao tree and to ferment, roast and grind cacao beans. The word cacao comes from the ancient Olmec word "kakawa."

In ancient Mesoamerica, dried and roasted cacao nibs were ground into chocolate paste by hand using a metate and mano, similar to a mortar and pestle. The paste was then mixed with water and flavorings to make a thick, frothy drink. It was time-consuming and difficult to make, which made it a luxury reserved for the elite.

This process would remain largely unchanged for centuries, and chocolate would remain a luxury for the wealthy, until technological innovations during the Industrial Revolution brought it within reach of the masses.

Watch Colonial Williamsburg Food Historian Jim Gay demonstrate how chocolate was made in the 1700s at youtube.com/watch?v=HvWTeOYJOdA.



Watt's Steam Engine. Wikimedia Commons

1789
Steam engine

In 1769, Scottish engineer James Watt took out a patent for "A New Invented Method of Lessening the Consumption of Steam and Fuel in Fire Engines." Watt's design greatly improved the efficiency and power of earlier steam engines.

Scale working model of the steam engine built for J.S. Fry, & Sons Ltd. in 1878 and used to drive the machinery in their No 3 factory in Bristol, England. ©Bristol Culture, M Shed museum

Reliable, consistent steam power soon powered factories previously powered by wind or water. Unlike wind- and water-powered engines, steam engines could be located anywhere. The steam engine became a major driver of the Industrial Revolution.

In 1789, English confectionary company Joseph S. Fry and Sons purchased a Watt's steam engine to grind cacao beans, marking the beginning of the mechanization of the chocolate-making process and the mass production of chocolate.

1828
beginning of large-scale production

In 1728, Englishman Walter Churchman developed a water engine to power his chocolate mill in Bristol, England, marking the beginning of large-scale chocolate production.

Sources: Sophie D. and Michael D. Coe, "The True History of Chocolate"; Louis Evan Grivetti and Howard-Yana Shapiro, "Chocolate: History, Culture and Heritage"; Britannica; History.com; Library of Congress; National Geographic

Menu from President Abraham Lincoln's second inaugural ball in 1865, featuring three types of chocolate. Smithsonian Institution

1865
Abraham Lincoln's second inaugural ball menu features chocolate in three forms: an edible sculpture made of chocolate, chocolate ice cream and a chocolate drink.

1868
Richard Cadbury introduces the first "chocolate box," containing chocolate candies and decorated with a painting of his daughter Jessica holding a kitten.

1875
The first milk chocolate bar is produced by Swiss chocolate manufacturer Daniel Peter, who combined powdered milk invented by Swiss chemist Henri Nestlé with cocoa solids and cocoa butter.

1876
Milton Snavely Hershey establishes a candy business in Philadelphia, after having been apprenticed at age 15 in a Lancaster, PA, confectionery store.

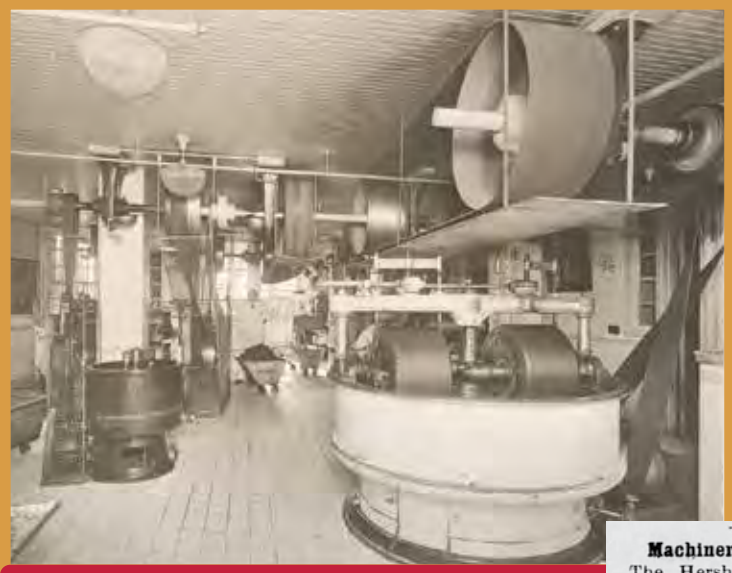
1879
Swiss chocolate maker Rodolphe Lindt invents the process of conching, which blends chocolate into a smooth, non-gritty product with better "mouthfeel."

IMPROVEMENTS IN CHOCOLATE GRINDING TECHNOLOGY

Above: A metate and mano. Earl McDonald, National Archives and Records Administration

Right: Chocolate liquor mill used in the Hershey chocolate factory from about 1920 to the late 1970s. National Museum of American History

Far right: Scale working model of a moving roller chocolate melangeur (mixer), said to have been used on the Fry's Show Train as part of a model chocolate factory. ©Bristol Culture, M Shed museum



Above: Modern ALPHA200 (Abi 200) commercial chocolate grinder. *Cocoatown*

Left: Chocolate liquor mill used in the Hershey chocolate factory from about 1920 to the late 1970s. National Museum of American History

Machinery for Chocolate Factory.

The Hershey Choclate Company at Derry Church is receiving machinery daily. The company received three large engines from Harrisburg, one of one-hundred-horse power and the other two are each of one hundred and fifty horse power. A large fire pump with a twelve inch section which throws fire hundred gallons of water per minute was also received.

Lebanon Courier and Semi Weekly Report, March 2, 1904

1890s

Swiss confectioner Jean Tobler develops the process of tempering chocolate, producing the shiny finish and "snap" when a chocolate bar is broken.

Chocolate production becomes industrialized with the introduction of advanced machinery, increasing production capacity and making chocolate more affordable and accessible.

1893

Whitman's Chocolates creates Easter bunnies.

1900

Milton Hershey sells his caramel candy business and builds a factory complex near his birthplace in rural Pennsylvania. Due to the remote location of the factory, Hershey also constructs a town for his employees.

1908

The Tobler candy company invents a chocolate bar in sections shaped like the Swiss Alps.

1911

Frank Mars begins his candy-making venture in the kitchen of his Tacoma, WA, home.

GOING BEYOND THE TEXT

James Watt steam engine

James Watt's steam engine ushered in a wave of industrialization, first in Britain and then around the world, that transformed the world economy, society, politics and environment.

Watch the six-minute video "James Watt Steam Engine" by Engineering Education at youtube.com/watch?v=UVBq27luj8A, then answer the following questions:

- What principle drives the Newcomen steam engine?
- What specific problems did Watt find with the Newcomen steam engine when he was asked to repair one?
- What was one specific improvement made by Watt?
- What was one specific advantage of the Watt engine over the Newcomen engine?
- List at least three industries that were transformed by steam power.

Florida Standards: ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.3.1; ELA.68.F.2.2; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.4.1; ELA.68.C.5.1; ELA.68.R.2.1; ELA.68.R.3.2; ELA.68.V.1.1

Scientific technology

Scientific inventions and technology have made life a little easier – and tastier – throughout the centuries. Each day, we enjoy many benefits of past and new scientific discoveries and technology. Look in the Tampa Bay Times for articles, images and advertising to find at least 10 different inventions used in your everyday life. Create a poster depicting the inventions. Next to each invention, write down the benefit of technology to that product. Next, using the items you have found in the Times, create a list of items you think will be improved or replaced in the next 20 years. Annotate your list by explaining what present technology may produce to replace or improve each of those items. Share what you have learned with your class.

Florida Standards: SC.68.N.1.1; SS.8.A.4.6; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.C.4.1; ELA.68.R.2.2

GOING BEYOND THE TEXT

Chocolate survey

In this activity, students will work in small groups to design and conduct a school-wide survey about chocolate.

Each group will create five questions. When creating questions, keep these points in mind:

- Use simple language.
- Keep questions short and to-the-point.
- Avoid biased or leading questions that encourage participants to respond in a certain way.
- Avoid double-barreled questions. (Double-barreled questions are questions that contain more than one question.)

Possible questions include:

- Do you prefer hot chocolate or cold chocolate milk?
- How often do you consume chocolate?
- What is your favorite chocolate product?
- What plant does chocolate come from?
- What part of the plant does chocolate come from?
- Where was chocolate first made?

Once groups have finalized their questions, survey your peers and record their answers. Once the survey is complete, create a bar graph to illustrate your findings. Present your graph and conclusions to your class.

Sources: "National Geographic Educator's Guide: Global Stories Where Chocolate Sparked Discovery, Innovation, and Imagination"
Florida Standards: SC.6.PE.2.1; MA.K12.MTR.2.1; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68. EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.R.2.2

DIGGING DEEPER

Being an entrepreneur

Thanks to the invention of the cocoa press and the processes of tempering and conching, there are many varieties of chocolate available for humans around the world to enjoy.

Have your teacher break up the class into small groups. Have each student in the group name some of their favorite chocolate candies. Discuss each candy's name and wrapper or other packaging. Are the name and packaging effective? Why or why not?

Next, as a group, you will be inventing your own chocolate candy. It could be in the form of a bar or some other form, such as small pieces in a bag or box. The first step is to describe the product and draw a picture of it, showing what the candy looks like on the inside as well as the outside. Second, give the product a name and design the candy's wrapper or packaging to make the product inviting. You will need to determine what information to include on the packaging and then draw it. You can put the descriptions and drawings on a poster board or on the computer. You may even want to make a 3D model of the product in its packaging.

Finally, using the advertisements in the Tampa Bay Times as models, create an advertisement for your new product. Share the new product and advertisement with the other groups in your class.

Adapted from: "National Geographic Educator's Guide: Global Stories Where Chocolate Sparked Discovery, Innovation, and Imagination"
Florida Standards: SC.68.N.1.1; SS.8.A.4.6; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.R.2.2

History of chocolate manufacturing continued

Van Houten cocoa press. Worldstandards.eu

Arkansas Democrat, Jan. 1, 1891

1828

Cocoa press

In 1828, Dutch chemist Coenraad Johannes Van Houten patented a process for separating cocoa butter from cocoa solids using a hydraulic press.

The cocoa press squeezed the cocoa butter out of the chocolate liquor, producing pure cocoa butter and a "cake" of cocoa solids that could be pulverized into a fine powder – what is now called cocoa powder.

Van Houten's invention made possible the large-scale manufacture of cheap chocolate cocoa for the masses.

The concept of pressing remains basically the same today, although modern industrial presses can process several tons of chocolate liquor per hour.

Paper and foil-wrapped Fry's Chocolate Cream Tablet chocolate bar, 1920s. ©Bristol Culture, M Shed museum

Paper and foil-wrapped Fry's Chocolate Cream chocolate bar, 1930s. ©Bristol Culture, M Shed museum

Field Ration D, a ration bar produced by the Hershey Chocolate Corporation for the U.S. military that weighed four ounces, would not melt at high temperatures and was high in food energy value. National Museum of American History

1925

The New York Cocoa Exchange is established at the World Trade Center to enable commercial transactions between cocoa buyers and cocoa sellers.

N.Y. COCOA EXCHANGE OPENS FIRST BAG BRINGS $1025

NEW YORK, Oct. 1.—Sale of a bag of cocoa for $1025 marked the opening today of the New York cocoa exchange at 124 Water street, the only institution of its kind in the world.

The bag, donated by Wood & Selick, Inc., was sold for $500 to a pool of members of the new exchange, who re-donated it. A second sale to a similar pool brought a price of $300 and the third of $225, to Rockwood & Co.

Proceeds from the sale will go to the Broad Street hospital and the contents of the bag will be served to patients.

The Buffalo News, Oct. 10, 1925

Amelia Earhart with Peter's Chocolate bar. Peter's Chocolate

1935

Amelia Earhart enjoys a cup of hot chocolate during her solo flight from Hawaii to Oakland, CA. "Drinking hot chocolate alone over the Pacific at 8,000 feet is a unique experience I shall not soon forget." Amelia Earhart, "My Flight from Hawaii," National Geographic, May 1935.

1938

Ruth Wakefield, who ran the Toll House restaurant in Whitman, Massachusetts, mixes a batch of cookies when she decides to add broken pieces of Nestlé Semi-Sweet chocolate into the recipe. She expects the chocolate to melt. Instead, the semi-sweet bits hold their shape – and the chocolate chip cookie is born.

1847

The solid chocolate bar

Dr. Joseph Fry began making chocolate by hand in the 1750s. In 1761, he purchased Walter Churchman's business, water engine, patent and recipes.

In 1847, Joseph S. Fry and Sons found a way to mix a blend of cocoa powder and sugar with melted cocoa butter, instead of with water. This produced a thin paste that could be cast in a mold, resulting in the first solid chocolate bar. The bar, named "Chocolat Délicieux à Manger" (Delicious Eating Chocolate) was coarse and gritty, but proved very popular.

Interior of the Lindt & Sprüngli factory. Chocoladefabriken Lindt & Sprüngli AG

Interior of the Lindt & Sprüngli factory. Chocolade-fabriken Lindt & Sprüngli AG

Diagram of Rodolphe Lindt's chocolate conch. Chocoladefabriken Lindt & Sprüngli AG

This conche was manufactured in approximately 1920 and was in use at the Hershey Chocolate Company. National Museum of American History

Fry's factories nos. 1 & 2 in Bristol, England. ©Bristol Culture, M Shed museum

1879

Conching

In 1879, Swiss chocolate maker Rodolphe Lindt invented the process of conching, which blends chocolate into a smooth, non-gritty product with better "mouthfeel."

Conching involves heating and mixing the chocolate liquor for hours or even days. Working the paste for this length of time disperses the cocoa solids in the cocoa butter, improving the texture and flavor of the chocolate.

Lindt's conche had a flat granite bed with curved ends. Granite rollers worked the chocolate liquor back and forth for up to 96 hours.

Modern conches function in essentially the same way but afford much greater control over the process.

Rodolphe Lindt. Chocoladefabriken Lindt & Sprüngli AG

Rodolphe Lindt's chocolate conche. Chocoladefabriken Lindt & Sprüngli AG

1890

Tempering

In 1890, Swiss confectioner Jean Tobler developed the process of tempering chocolate, producing the shiny finish and "snap" when a chocolate bar is broken.

Shutterstock

As you learned on pages 8-9, chocolate is polymorphic – it can crystallize into six different forms. The process of tempering involves carefully controlling the temperature of cooling chocolate to ensure that it crystallizes into Type 5, which produces a shiny, smooth texture, good snap, and melt-in-the-mouth finish.

Sources: Sophie D. and Michael D. Coe, "The True History of Chocolate"; Louis Evan Grivetti and Howard-Yana Shapiro, "Chocolate: History, Culture and Heritage"; Britannica; History.com; Library of Congress; National Geographic

1939
World War II rationing limits adults in Britain to 12 ounces of "sweets" every 4 weeks while in France, there is a special ration of about four ounces of chocolate monthly for children under two.

1953
Edmund Hillary and Sherpa Tenzing Norgay reach the summit of Mount Everest and leave an offering of a chocolate bar, biscuits and candy. Sweet rationing ends in Britain.

1960
Explorers Jacques Picard and Don Walsh feast on chocolate bars during their trip to the bottom of the Mariana Trench, the lowest point on Earth, in the vessel Trieste.

1961
Yuri Gagarin becomes the first person in space and eats from a tube of chocolate sauce.

1969
Chocolate pudding travels to the moon on Apollo 11, the first manned lunar landing.

1981
M&M's brand chocolate candies are included in the first space shuttle mission and every subsequent flight. They are included in NASA's space food system and are featured on the International Space Station menu.

Left: Astronaut Loren J. Shriver pursues several floating chocolate Mars candies on the flight deck of the Space Shuttle Atlantis in 1992. NASARight: Space Shuttle-era Mars advertisement. Mars, Incorporated

THE SCIENCE OF MOLTEN CHOCOLATE CAKE

RECIPE INGREDIENTS:

- 130 grams dark chocolate chips
- 120 grams unsalted butter (1 stick)
- 2 whole eggs plus 2 egg yolks
- 100 grams sugar
- 60 grams all-purpose flour
- Pinch salt

Density: Flour and sugar particles can pack more or less densely. Measuring quantities by weight rather than by volume is more accurate.

Wikimedia Commons

Denaturation is the process of the modification of the molecular structure of a protein. Proteins generally look like coiled-up balls of string. When they're exposed to heat energy, the protein strings unravel and get tangled up with their neighbors.

RECIPE DIRECTIONS:

1. Preheat the oven to 350 °F (177 °C). Spray 8 ramekins with nonstick baking spray.
2. In a small saucepan, melt the chocolate chips and butter together over low heat, stirring constantly.

Phase transitions: As you learned on pages 10-11, the exact temperature at which chocolate melts is determined by which of the six different types it is. Each type melts at a different temperature.

3. In a medium bowl, whisk together the eggs, egg yolks and sugar.

Solubility: Sugar will begin to dissolve in the water contained in the egg white. Sugar is highly soluble in water. At room temperature, a given quantity of sugar can dissolve in half the amount of water by weight.

4. In another bowl, whisk together the flour and salt.
5. Slowly add the chocolate mixture to the egg mixture, whisking constantly.

Protein denaturation: Adding the hot chocolate-butter mixture to the eggs too quickly will cause the egg proteins to denature, or "cook." Denaturation is the process of the modification of the molecular structure of a protein. Proteins generally look like coiled-up balls of string. When they're exposed to heat energy, the protein strings unravel and get tangled up with their neighbors. To avoid that outcome, add a little of the mixture at a time while constantly whisking.

6. Little by little, add the flour mixture to the wet ingredients and whisk well. Make sure the flour is completely incorporated.

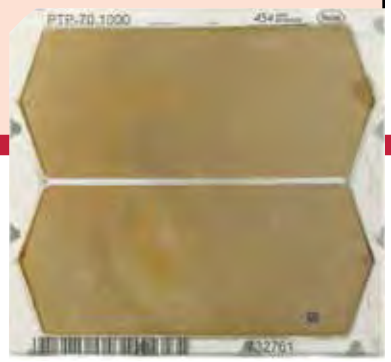
Viscosity, polymers, emulsions and foams: The final batter's viscosity is determined by the various ingredients. Whisking causes the starch particles in the flour to swell and leak polymers. The polymers entangle and form a network that, together with the swollen starch particles, increases the viscosity of the batter. Whisking also incorporates air and creates a foam. The result is an emulsion of fat (butter) and water (egg white). The final viscosity depends on the volume fraction of air bubbles and fat droplets along with the packing density of starch particles and the network of polymers.

7. Fill the prepared ramekins with batter so that they are a little more than half full (1.5 cm to 2 cm from the top).
8. Place the ramekins on the middle rack of the oven and bake for 12 minutes.

Solubility of gases and foams: When heated in the oven, the cakes rise because the air in the batter expands. In addition, the solubility of carbon dioxide decreases with higher temperatures, so the CO^2 diffuses out of the batter and helps form the bubbles in the cake.
Heat diffusion: How far does heat diffuse in 12 minutes? To answer that question, measure the thickness of the cooked layer. As the cake bakes, the batter around the edges reaches the temperature at which it solidifies and forms a "crumb front" that moves toward the center of the cake. The characteristic molten center consists of batter that is heated but not cooked.

9. Serve warm, preferably topped with ice cream!

Source: Physics Today, "The science behind molten chocolate cake" by Michael Brenner, Pia Sörensen and David Weitz
Florida Standards: SC.68.N.1.1; MA.67.AR.3.5; ELA.68.EE.2.1; ELA.68.F.2.4



Left: This picotiter plate held DNA samples from Costa Rican cacao trees during analysis to sequence the cacao genome. The genome sequencing was part of a collaboration to work toward developing disease-resistant cacao trees and ensuring a stable cacao supply. National Museum of American History; and Right: These tools were used by workers at the Mars Center for Cocoa Science in Itajuipe, Bahia, Brazil, in their cacao hybridization efforts. While sequencing the cacao genome provided scientists with a road map to understanding cacao and accelerated testing techniques, scientists still bred new cultivars of cacao through traditional techniques of hand pollination. National Museum of American History

2002
The U.S. Food and Drug Administration establishes a standard of identity for white chocolate.

2006
Mars Chocolate develops AMERICAN HERITAGE Chocolate, a historic chocolate brand fashioned from chocolate recipes of the mid-1700s.

2010
Mars, IBM, and the U.S. Department of Agriculture complete a two-year, $10 million effort to sequence and annotate the cocoa genome. The genome is placed in the public domain.

2014
The Hershey Company and 3D Systems unveil the CocoJet, a 3D chocolate printer that can create elaborate shapes in dark, milk or white chocolate. The product never makes it to market.

THE SCIENCE OF CHOCOLATE CHIP COOKIES

RECIPE INGREDIENTS:

- 280 grams all-purpose flour
- 1 teaspoon baking soda
- 1 teaspoon salt
- 227 grams butter, softened (2 sticks)
- 150 grams sugar
- 165 grams packed brown sugar
- 1 teaspoon vanilla extract
- 2 large eggs
- 2 cups (12-ounce package) semi-sweet chocolate chips

Density: Flour and sugar particles can pack more or less densely. Measuring quantities by weight rather than by volume is more accurate.

RECIPE DIRECTIONS:

1. Preheat oven to 375° F.
2. Combine the flour, baking soda and salt in a small bowl.
3. Beat the butter, sugar, brown sugar and vanilla extract in a large bowl until light and fluffy.

Moisture content: Granulated white sugar has a very low moisture content. Brown sugar is made with molasses, so it has more moisture content. The more white sugar you have, the crispier your cookie will be. The more brown sugar you have, the softer your cookie will be.

4. Add the eggs one at a time, beating after each addition.
5. Gradually beat in the flour mixture just until it's combined.

Proteins: Grains like wheat contain a mixture of two proteins, called glutenin and gliadin. When flour made from these grains is mixed with water, the two proteins combine to form gluten.

The gluten, or protein, combines to form a web that traps air bubbles and sets. Starch in flour sets as it heats to add to and support the structure.

6. Stir in the chocolate chips.
7. Drop the dough by rounded tablespoon onto ungreased baking sheets.
8. Bake for 9 to 11 minutes or until golden brown.

Solubility of gases and foams: As the butter melts, its water is released, dissolving the baking soda and eventually turning to steam. The baking soda reacts with acids in the dough, creating carbon dioxide gas bubbles that, along with the steam, cause the cookies to rise.

Protein denaturation: As they are heated, the egg proteins in the dough begin to denature, or "cook." Denaturation is the process of the modification of the molecular structure of a protein. Proteins generally look like coiled-up balls of string. When they're exposed to heat energy, the protein strings unravel and get tangled up with their neighbors, forming a solid cookie.

Maillard reaction: The sugar reacts with the proteins in the eggs and flour in a process called the Maillard reaction, producing the cookie's nutty, savory toasted flavors. As you learned on pages 6-7, the Maillard reaction occurs when proteins and sugars in and on your food are transformed by heat, producing new flavors, aromas and colors.

9. Cool on baking sheets for 2 minutes; remove to wire racks to cool completely.

Phase transitions: As your cookies cool, the previously liquified ingredients solidify.

Sources: Institute of Culinary Education, "Understanding the Science of Cookies" by Pamela Vachon; Nestlé; TEDEd, "The chemistry of cookies"
Florida Standards: SC.68.N.1.; MA.67.AR.3.5; ELA.68.EE.2.1; ELA.68.F.2.4

GOING BEYOND THE TEXT

DIGGING DEEPER

Out of this world

Did you know that the first space shuttle mission in 1981 carried M&M'S® included in the astronauts' food rations? These were not the first chocolates in space, though. That honor goes to a tube of chocolate sauce carried by the first person in space – Russian cosmonaut Yuri Gagarin – in 1961.

Chocolate has become a regular treat for astronauts and cosmonauts. Every six months, "bonus containers" of food items are sent to the International Space Station (ISS) to supplement the balanced meals. Imagine you are living on the ISS for several months and a spacecraft with bonus containers is being sent to your team. What five items would you request be included? At least one of the items you request must be chocolate. Keep in mind that the items you select must be able to travel through space.

Now that you have made your selections, you must put in an official request to NASA. Using the letters to the editor in the Tampa Bay Times as models, write a 250-word letter to NASA requesting your five special items and explaining why you chose each item.

Adapted from: "National Geographic Educator's Guide: Global Stories Where Chocolate Sparked Discovery, Innovation, and Imagination"
Florida Standards: SC.68.N.1.1; SC.8.E.5.12; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.R.2.2

2022
The Cocoa Supplement and Multivitamin Outcomes Study (COSMOS) finds that a cocoa extract supplement containing flavanols reduced deaths from cardiovascular disease by 27%.

2023
Cocoa Press announces the launch of their chocolate 3D printer, the Cocoa Press. It is available as a DIY kit or preassembled.

Watch Adam Savage's Tested test out the Cocoa Press at youtube.com/watch?v=mLgk7KkOZ60!

2025
A research team at Penn State creates disease-resistant cacao plants by editing the gene TcNPR3 in cacao plants using the gene editing technology CRISPR-Cas9.

Timeline sources:
AMERICAN HERITAGE Chocolate; History.com; "National Geographic Educator's Guide: Global Stories Where Chocolate Sparked Discovery, Innovation, and Imagination" National Museum of American History; Palace of Versailles

About AMERICAN HERITAGE Chocolate and the Forrest E. Mars, Jr. Chocolate History Grant

This project was funded by a Forrest E. Mars, Jr. Chocolate History Grant from AMERICAN HERITAGE Chocolate, a Mars Wrigley brand.

Launched in 2013, the Forrest E. Mars, Jr. Chocolate History Grant has a special emphasis on uncovering and sharing chocolate's role in global history as well as its influence on heritage and culture. Grant funds support projects that investigate and/or educate on the history of chocolate, uncover new chocolate innovation, development of cocoa science as well as highlight the chocolate-making process.

In 2024, AMERICAN HERITAGE Chocolate launched a Classroom Resource Grant for teachers of K-12 students in the United States.

For more information about AMERICAN HERITAGE Chocolate and the Forrest E. Mars, Jr. Chocolate History Grant, visit americanheritagechocolate.com.

For even more chocolate, check out our HISTORY OF CHOCOLATE curriculum supplement and teacher guide!

About NIE

Tampa Bay Times NIE newspaper in education tampabay.com/nie

The Pulitzer Prize-winning Tampa Bay Times is the largest daily newspaper in Florida. Locally owned and independent, the Times has long been celebrated for its outstanding and credible journalism, practiced with integrity in the public interest. The Times has been part of the Tampa Bay community for more than 140 years.

The Tampa Bay Times Newspaper in Education program (NIE) is a cooperative effort between schools and the Times to encourage the use of newspapers in print and electronic form as educational resources – a "living textbook."

Since the 1970s, NIE has served educators, students and families in the Tampa Bay area by providing classroom access to the Times plus award-winning original educational publications, teacher guides, lesson plans, educator professional development resources and much more – all at no cost to schools, teachers or families. Our educational resources fall into the category of informational text, a type of nonfiction text. The primary purpose of informational text is to convey information about the natural or social world.

NIE is a member of Florida Press Educational Services (FPES), a 501(c)(3) nonprofit organization of Florida newspaper professionals whose mission is to promote literacy, civic engagement and critical thinking, particularly for young people. Learn more at fpesnie.org.

For more information about NIE, visit tampabay.com/nie, call 727-893-8138 or email ordernie@tampabay.com. Follow us on Facebook at facebook.com/TBTNIE.

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Florida Standards

This publication and its activities incorporate the following Florida Standards for middle school students.

SC.68.N.1.1; SC.68.N.1.3; SC.6.N.1.5; SC.6.PE.2.1; SC.7.N.1.4; SC.7.L.17.1; SC.7.L.17.3; SC.8.P.8.1; SC.8.P.8.4; SC.8.E.5.12; ELA.68.EE.1.1; ELA.68.EE.2.1; ELA.68.EE.4.1; ELA.68.C.5.1; ELA.68.EE.6.1; ELA.68.F.2.2; ELA.68.F.2.3; ELA.68.F.2.4; ELA.68.C.1.3; ELA.68.C.1.4; ELA.68.C.1.5; ELA.68.C.2.1; ELA.68.C.3.1; ELA.68.R.2.1; ELA.68.R.2.2; ELA.68.R.3.2; ELA.68.V.1.1; MA.67.AR.3.5; MA.K12.MTR.2.1; SS.8.A.4.6; SS.6.G.3.1; SS.6.G.3.2; SS.8.G.5.2

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