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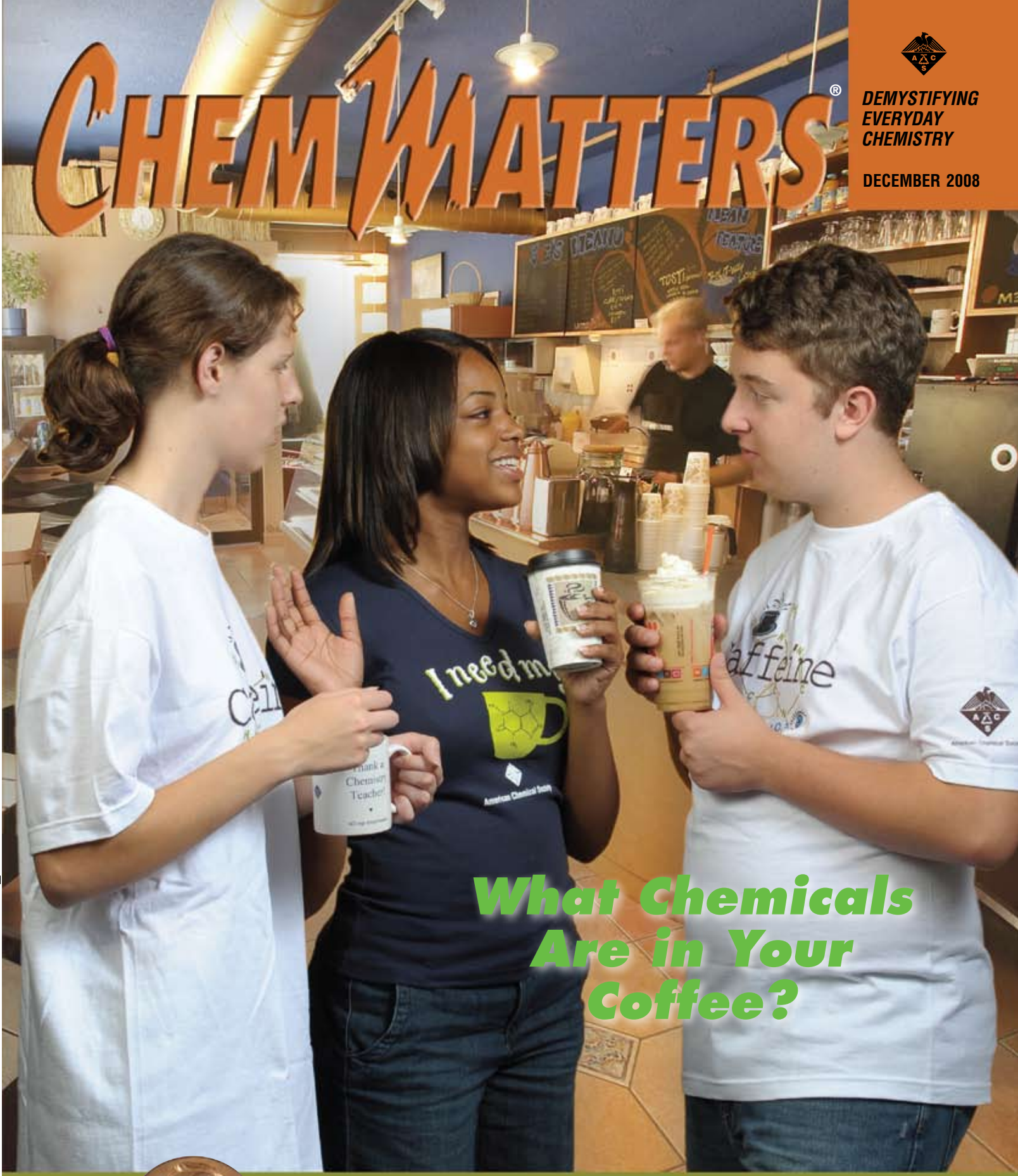

What Chemicals Are in Your Coffee?

2008 Nobel Prize in Chemistry: Glowing Proteins with Promising Biological and Medical Applications

QUESTION FROM THE CLASSROOM

By Bob Becker

Q. I saw this video on YouTube that showed a guy breathing in a gas from a balloon. Unlike helium, instead of making his voice higher, this gas made his voice much lower. It was amazing! What was the gas?

A. The gas was a compound called sulfur hexafluoride. As the name implies, its molecules are made of one sulfur atom and six fluorine atoms (Fig. 1). One might think that a compound made of sulfur (used in making matches and gun powder) and fluorine (the most reactive nonmetal) would be too dangerous to handle, let alone breathe in. But these two highly reactive elements form such a stable bond that the resulting compound is almost as inert as a noble gas—one of the gases listed in the last column of the periodic table (helium, neon, argon, etc.).

That does not necessarily make it safe to breathe in! The first hazard associated with breathing in helium and sulfur hexafluoride is that impurities may be present in the tank storing the gas, which may include oils in the valves and regulators or toxic hydrogen fluoride gas.

The second hazard is that these gases do not provide oxygen, which our body depends on 24/7. You might think then that breathing in one of these gases for a short while would be no worse than just holding your breath for that same amount of time. Actually, when you hold your breath for 15 to 20 seconds, you are immediately aware that something is wrong and your body instinctively feels the urge to gasp for a fresh breath of air. Surprisingly, that gasping reflex is not triggered by the lack of oxygen in the blood but by the buildup of carbon dioxide in the bloodstream because you didn't breathe out!

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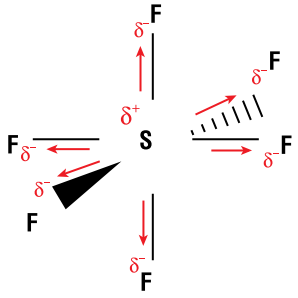
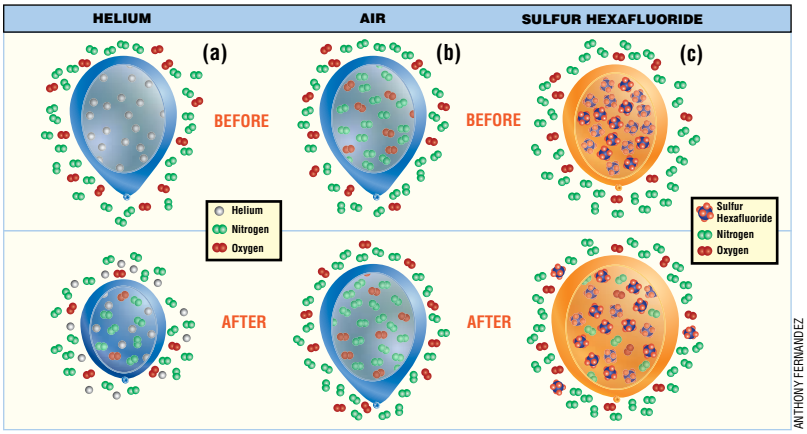


Figure 1. Molecular structure of sulfur hexafluoride. Electrons move from the center of the molecule to the periphery (red arrows), creating a small charge imbalance that makes the center slightly more positively charged (δ^+) than a single sulfur atom and the fluoride atoms in the periphery slightly more negatively charged (δ^-) than single fluorine atoms. But overall, the molecule is nonpolar because all these charges cancel out.



ANTHONY FERNANDEZ

Figure 2. (a) A balloon filled with helium gas tends to deflate quickly as more helium leaks out than oxygen and nitrogen molecules from the air enter the balloon; (b) A balloon filled with air stays more or less the same from one day to the next; (c) A balloon filled with sulfur hexafluoride inflates because only a few sulfur hexafluoride molecules leak out while relatively more oxygen and nitrogen molecules from the air enter the balloon.

So, say you breathe in helium, talk funny, laugh a little then breathe out—expelling all the carbon dioxide from your lungs—and then breathe in some more helium, sing a Munchkin song, laugh some more, breathe out some more carbon dioxide … . All the while, you don't breathe in any oxygen and are completely unaware of the fact that you are actually suffocating, which can happen in a very short period of time. This is why some people tend to overdo helium breathing and end up passing out, which can make them fall without warning and cause injury.

Sulfur hexafluoride has some rather peculiar properties. The fluorine atoms have a very strong attraction for electrons—which means that the electrons shared between the sulfur and the fluorine spend disproportionately more time near the fluorine atoms, giving them a partial negative charge. But because the molecule of sulfur hexafluoride is completely symmetrical, these polar bonds all cancel out and create a nonpolar molecule (in which the electrons are symmetrically distributed—mostly on the fluorines). This explains why sulfur hexafluoride is a gas at room temperature and remains so all of the way down to –64°C.

Perhaps the most remarkable effect associated with sulfur hexafluoride can be observed when the gas is put into a balloon and just left there (Fig. 2). A balloon filled with helium gas tends to deflate quickly as the helium leaks out, and a balloon filled with air stays more or less the same from one day to the next. But a balloon filled with sulfur hexafluoride will grow in size!

A helium balloon decreases in size over time because the helium atoms inside are moving so fast that they can leak out more quickly than the air molecules outside can leak in. An air-filled balloon maintains its size because the air molecules inside leak out at about the same rate as the air molecules outside leak in. And a balloon filled with sulfur hexafluoride increases in size over time because the air molecules outside leak into the balloon more quickly than the sulfur hexafluoride molecules inside leak out. Cool, huh?

The original YouTube video can be found at http://www.youtube.com/watch?v=vcVMjGRzDz8&feature=related.

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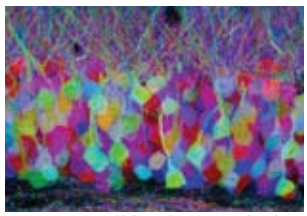

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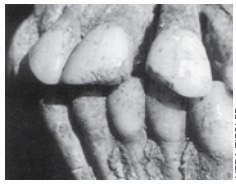

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Brain Booster to Go?

By Gail Kay Haines

The first buzzer sounds in seven minutes, and you are still in line at Starbucks. Classmates streak across the street, backpacks flapping and cardboard cups in hand. You already have one tardy this quarter, so maybe you'd better forgo that triple shot mocha grande. But there is a test in chemistry, second period, and you need the boost to get your brain moving. Decisions, decisions.

A hot trend in senior and junior high schools around the country is coffee-shop coffee—the fancier the better. Sometimes, it is not even hot. Coffee-and-crushed-ice concoctions are especially popular. Sugar, whipped cream, pile it on! Chains or local favorites—even a coffee bar in the school lunchroom—offer upscale coffee.

High-calorie extras aside, a cup of coffee is hot water pushed through a scoop of roasted and powdered beans. More than 800 different chemicals go into that famous aroma, making coffee brown and rich, bitter and sweet, stimulating and soothing. When it comes to coffee, it's all in the chemistry.

But will it help you ace your chemistry exam? And is it worth the price—to your nervous system, as well as your wallet?

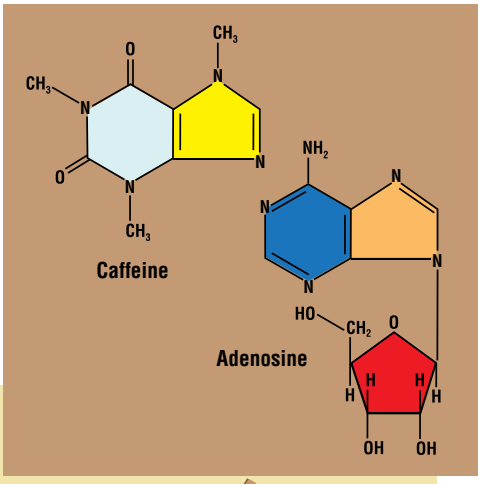
Let's sift the evidence.

How coffee works in the brain

For most coffee drinkers, the underlying allure of coffee is caffeine, the most widely consumed mind-altering chemical in the world. "Caffeine" is the common name for 1,3,7-trimethylxanthine ($C_8H_{10}N_4O_2$), a bitter white powder found in more than 60 kinds of plants around the world, including tea, yerba mate (a popular beverage in South America), and kola nuts.

A brain chemical called adenosine regulates drowsiness. When you are tired, adenosine builds up inside your brain and attaches to proteins on brain cells called adenosine receptors, causing drowsiness. As you drink coffee, molecules of caffeine get inside the brain and bind to these adenosine receptors (Fig. 1), but unlike adenosine, caffeine excites brain cells.

If caffeine blocks enough receptors, you can stay awake for hours, after which the caffeine molecules are broken down and eliminated. Usually, caffeine is effective 15 minutes to 1 hour after your last latte, and the peak lasts about 3 to 3 1/2 hours.



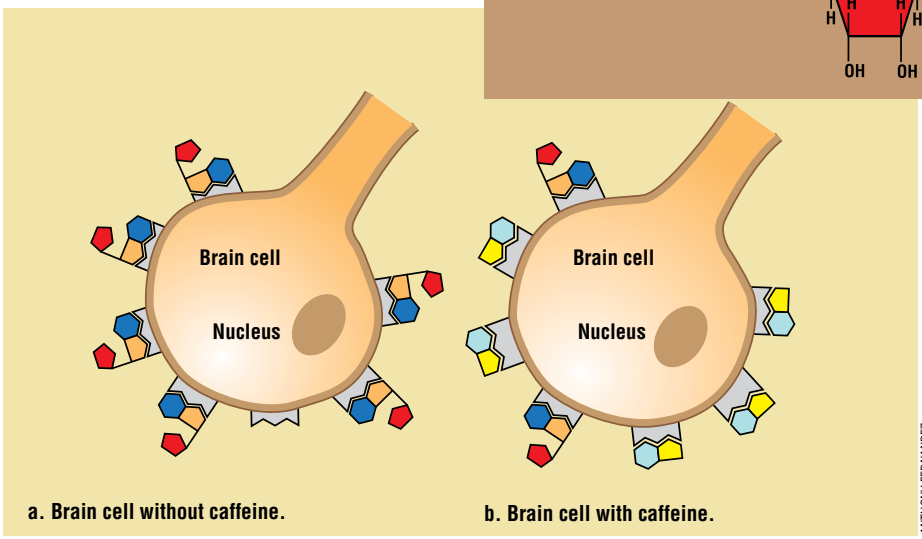


Figure 1. Caffeine and adenosine molecules have similar shapes, so they can both bind to proteins on brain cells called adenosine receptors. When you feel sleepy (a), adenosine molecules bind to most of these receptors, but when you drink coffee (b), some caffeine molecules attach to these same receptors, making you alert instead of sleepy.

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Chemicals in coffee

Scientists have identified more than 800 chemicals in coffee beans, including caffeine, sucrose, and cellulose. Others include proteins and acids such as citric acid, which is found in acidic fruits; tartaric acid, the main acid in wine; and formic acid, the stinging poison secreted by ants.

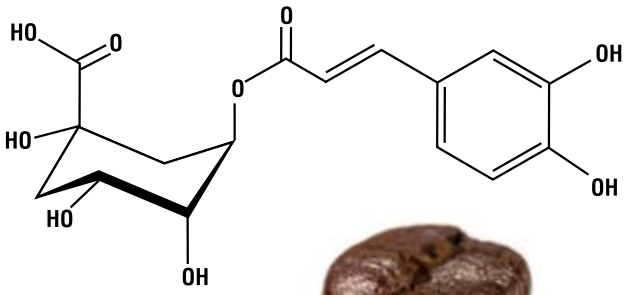
When coffee is roasted, chemical reactions inside the beans destroy some molecules and create new ones. There are different degrees of roasting. Some people prefer lightly roasted coffee—roasted barely a few minutes—while others like it better when the beans have roasted for half an hour. In each case, the chemical composition of the coffee is different.

As coffee beans absorb heat (at temperatures between 188 °C and 282 °C), their color shifts from green to yellow to light brown, and then to dark brown. Oils make their surface shiny. Chemical reactions inside the beans turn carbohydrates and fats into aromatic oils, burn off moisture and carbon dioxide, and alternately break down and build up acids, unlocking the characteristic coffee flavor.

Robert Benck, roastery manager at Batdorf and Bronson Coffee Roasters, Olympia, Wash., started working with coffee while in college. "Both my chemistry and Spanish classes have been useful in my career," he says as he stands in a warehouse filled with *Coffea arabica* beans from places like Mexico, Guatemala, and Costa Rica.

Benck explains that as coffee beans roast, they first pop due to pressure inside and then swell and split. A chemical process, called the Maillard reaction, combines heated sugar and amino acids present in the beans to form hundreds of color and flavor molecules.

After about 12 minutes, a second pop can be heard, and the beans start oozing out oils. At both pops, and for several days after, roasted coffee beans give off carbon dioxide—so much that if coffee bags are sealed too quickly, they can burst.



Example of a chlorogenic acid

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Coffee is not only about caffeine

An important family of chemicals present in coffee is called chlorogenic acids. Scientists are discovering that chlorogenic acids may provide health benefits beyond caffeine's effects. These molecules make up between 6% and 12% of the chemicals present in green coffee beans, while caffeine is only 1% to 2% of the total.

Chlorogenic acids belong to a group of chemicals called antioxidants, which protect cells against damage from free radical molecules formed inside cells. Free radicals can damage DNA and have been associated with Alzheimer's disease, cardiovascular disease, cancer, and diabetes.

ROBERT BENCK

"Coffee is the number one source of antioxidants in the U.S. diet," says Joe Vinson, professor of chemistry at the University of Scranton, Pa. "Chlorogenic acids—primarily from coffee—are probably the major single antioxidant found in the diet."

Peter Martin, a professor of psychiatry and pharmacology at Vanderbilt University, Nashville, Tenn., and Adriana Farah, a chemistry professor at the Universidade Federal do Rio de Janeiro, Brazil, have studied chlorogenic acids and their antioxidant derivatives formed through chemical reactions in roasting coffee beans. They have concluded that light- to medium-roast coffees contain the most of these antioxidants.

"It is hard to know exactly the health effects of these various compounds since they act together," Martin says. "It's as if you were putting together a jigsaw puzzle, and you are studying one piece of the puzzle—that is, each chemical in coffee—at a time."

At Pavia University, Italy, Gabriella Gazzani and colleagues found that green coffee's antioxidant properties are mainly due to chlorogenic acids. Even though chlorogenic acids are degraded up to 70% when coffee beans are roasted, the more roasted the coffee is, the more it contains antioxidants called melanoidins, which are created through the Maillard reaction.

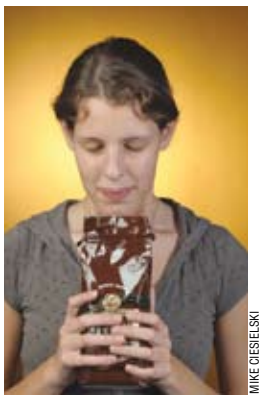
Chlorogenic acids are either absorbed by the stomach and the intestines or broken down into other compounds that are also antioxidants. Vinson and colleagues have shown that chlorogenic acids slow the release of glucose into the bloodstream after a meal, thus lowering blood sugar levels. Other studies show that they reduce the risk of hypertension and type 2 diabetes. Chlorogenic acids also may have other health properties, still being investigated.

Potential benefits against alcoholism and stress-related disorders

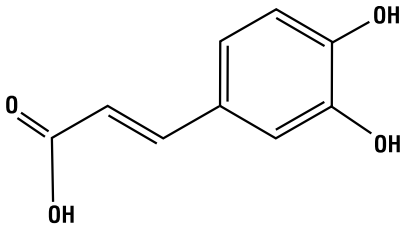
Martin and colleagues have made chlorogenic acid derivatives in their laboratory and studied their properties on the brain cells of rats. They have found that these chemicals bind to proteins on the surface of brain cells that also bind to drugs that reduce alcohol craving. These results show that consuming coffee may help people suffering from alcoholism.

Another team of scientists led by Yoshinori Masuo, a researcher at the National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan, has shown that simply inhaling the aroma of roasted coffee may have beneficial health effects. When sleep-deprived rats sniff coffee, proteins in their brain cells are activated to protect them from stress-related damage. In other words, chemicals in coffee's aroma, alone, can relieve stress.

"These results may provide a new way of relieving stress and maybe of helping in the treatment of mental disorders related to stress, including depression, autism, and attention-deficit hyperactivity disorder," Masuo says.



MIKE DIESELSKI

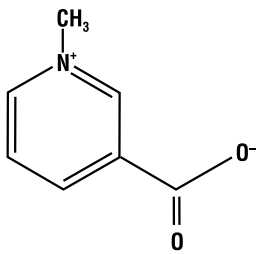


Caffeic acid

Additional health benefits of coffee

Coffee may also protect teeth. Farah, Gazzani, and Beatriz Gloria, a chemistry professor at the Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, have shown that chemicals in roasted—but not green—coffee inhibit the growth of bacteria that cause tooth decay.

The scientists found a variety of different antibacterial chemicals which killed or inhibited the growth of *Streptococcus mutans,* the major cause of dental decay in humans. Also, Gazzani and colleagues applied roasted coffee to hydroxyapatite, a component of tooth enamel—the hard white substance covering a tooth—and showed that small molecules present in coffee prevented *S. mutans* bacteria from binding to it.



Trigonelline

Coffee may also help kill bacteria that infect our guts and lungs. Gloria, Farah, and colleagues have shown that chlorogenic acids, trigonelline, caffeine, caffeic acid, and protocatechuic acid inhibit the growth of enterobacteria, which can cause food poisoning, diarrhea, and typhoid fever. The researchers suggest that these chemicals could be used in foods as a natural preservative to control bacterial growth.

Surprisingly, caffeine and cholorogenic acids may have opposing effects in the brain. Martin and colleagues have found that chlorogenic acid derivatives stimulate adenosine molecules to bind to brain cells, thus acting contrary to caffeine. So, when you drink coffee, the effects of caffeine and chlorogenic acids on brain cells seem to balance out.

Another interesting finding was recently made by Gloria and her team. They discovered that coffee contains tryptophan, a chemical converted by the body into a brain chemical called serotonin that helps regulate sleep, appetite, and mood, and inhibits pain.

So is coffee good for you?

Back to that chemistry exam second period. The timing is right. Your caffeine level will be at its peak. And, as many studies have shown, the drink will improve your mood and increase your mental alertness, cognition, and reaction speed—even your ability to do simple math problems. So far, so good. Will it make you smarter? You wish! There is absolutely no evidence linking coffee with increased brain power—just alert use of your brain.

And is caffeine addictive? Do you risk becoming a "java junkie?" Yes and no. Brains get so used to caffeine's effects that a withdrawal headache can result. But most experts agree that caffeine is not as addictive as illegal drugs, such as heroin and cocaine, because too much caffeine just makes you jittery, and withdrawal symptoms are mild. Caffeine is on the Food and Drug Administration's list of food additives that are "generally recognized as safe."

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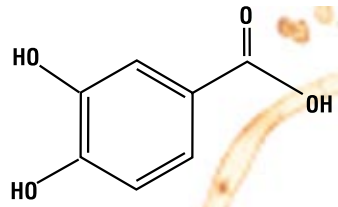

Protocatechuic acid

Here is the bottom line. If coffee works for you, that's great. But food experts suggest drinking no more than three cups of coffee per day. People who regularly consume more may find themselves restless, irritable, and sleepless. Also, some people have caffeine sensitivity. If just one small coffee gives you a red face and a pounding heart, stick to noncaffeinated beverages.

But if you enjoy a mocha in the morning or a latte with lunch, you have plenty of company. Coffee is experiencing a new renaissance, says the National Coffee Association, and it is enjoying yearly sales of more than $11 billion. Coffee is the most traded commodity next to oil and the world's most popular drink next to water.

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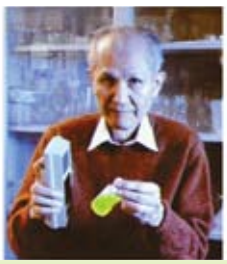
Gail Kay Haines is a science writer and book author from Olympia, Wash. Her most recent article, "Corn—The A"maiz"ing Grain," appeared in the December 2006 issue of *ChemMatters.*

Glowing Proteins with Promising Biological and Medical Applications


By Linda Zajac

Under the lens of a microscope, a mouse is still from anesthesia. Every few seconds, a camera captures images of brightly glowing cancer cells moving through the mouse's blood vessels. Robert Hoffman, a professor of surgery at the University of California, San Diego, studies the images of spreading cancer. Each cancer cell glows red, while its nucleus glows green. Some cancer cells roll and crawl on blood vessel walls while others collide and drift through the bloodstream.

Hoffman has spent the past 12 years developing an imaging technique that allows scientists to see growing tumors in live mice. Thanks to this technique, scientists around the world are able to follow cancer cells wherever they go in the body of animals affected by cancer. What makes this possible is a molecule called a fluorescent protein. By making proteins and cells glow, it brought about a revolution in biology and medicine by allowing scientists to actually see inside cells and better understand how viruses and tumors work.

The use of fluorescent proteins has been such a success that it landed this year's Nobel Prize in Chemistry to three scientists who discovered the first fluorescent protein: Osamu Shimomura, a Japanese citizen based in the United States, and Americans Martin Chalfie and Roger Tsien.

Before this protein was discovered, very few techniques offered a way of seeing what was happening inside the cell. Proteins are so tiny they can't be viewed under an electron microscope. But by attaching fluorescent proteins to these proteins, it is possible to constantly track their whereabouts. What's more, these fluorescent proteins are now available in many colors, so scientists can study different types of proteins by labeling them with different colors.

Here is the story of the scientists who discovered this protein, realized how it worked, and ultimately won the Nobel Prize and how other scientists found ingenious ways to use it to study diseases, such as cancer, Alzheimer's disease, and crop diseases.

Discovery of the green fluorescent protein

It all started in July 1961 when Osamu Shimomura, a senior scientist at the Marine Biological Laboratory in Woods Hole, Mass., and Frank Johnson, a scientist at Princeton University, decided to study what made crystal jellyfish glow in the dark.

Before joining Johnson, Shimomura had shown that tiny egg-shaped crustaceans called ostracods produced light through a process called bioluminescence, which is the emission of light by a living organism as a result of a chemical reaction. In the ostracod, bioluminescence is produced by a chemical reaction that adds oxygen (O_2) to a chemical called luciferin. The reaction is catalyzed by an enzyme called luciferase and leads to the production of an oxidized form of luciferin, carbon dioxide (CO_2), and light:

$$\text{luciferin} + O_2 \rightleftharpoons \text{oxidized luciferin} + CO_2 + \text{light}$$

The two scientists were wondering whether crystal jellyfish emitted light in the same way. So they traveled to Friday Harbor Laboratories in Friday Harbor, Wash., to collect jellyfish and determine what chemicals made them glow. After many weeks of work, Shimomura identified a molecule called aequorin as the probable cause of the bioluminescence of jellyfish.

In 1962, Shimomura, Johnson, and colleagues showed that, in the presence of calcium ions (Ca^{2+}), aequorin emitted blue light after splitting into two molecules—called apoaequorin, coelenteramide—and carbon dioxide (CO_2).

But jellyfish emit green light, not blue light. The researchers thought that another molecule was probably involved as well. After a few months, they found another protein, which they called the green fluorescent protein (GFP).

Pictured above: Martin Chalfie, Osamu Shimomura, and Roger Tsien received this year's Nobel Prize in Chemistry for the discovery of the green fluorescent protein, which, according to the Nobel Foundation, is "one of the most important tools used in contemporary bioscience."

In 1974, the scientists discovered that the blue light produced by aequorin was immediately absorbed by GFP, which then emits green light through a process called fluorescence (which happens when a molecule absorbs light and emits light of a different color).

Using fluorescent proteins as tracers inside cells

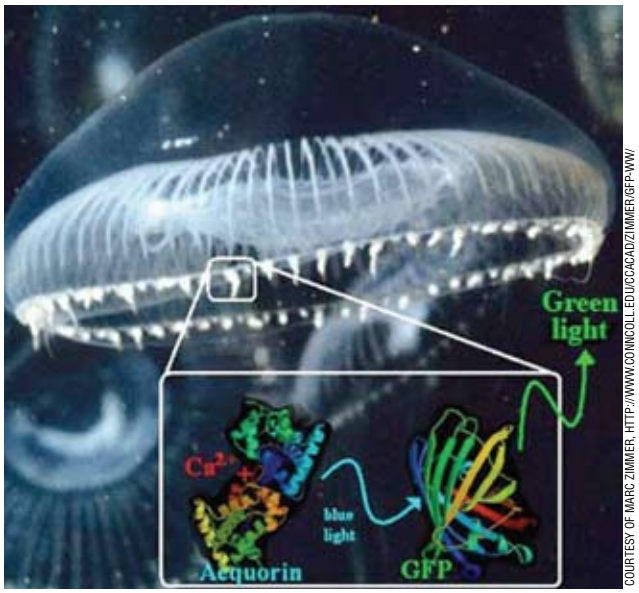
In 1987, Douglas Prasher, an assistant biochemist at the Woods Hole Oceanographic Institute, Woods Hole, Mass., thought it might be possible to attach GFP to a specific protein. If researchers could see cancer cells glowing, they could tell if the disease was spreading.

Prasher decided to look for the gene that produces GFP. He reasoned that after identifying this gene, he would insert it in the DNA of other organisms—including humans—to make proteins with GFP attached to them (Fig. 2). Then these proteins would be exposed to blue light that they would absorb to emit green light (in the same way as when GFP in jellyfish absorbs blue light from aequorin to emit green light). As a result, GFP would make proteins glow, allowing scientists to see them move through a cell.

In 1992, Prasher found the GFP gene and published his results in the journal *Gene*. Unfortunately, funding for his grant ran out before he could show that GFP could be used as a tracer, so he had to stop his research. But before leaving Woods Hole, Prasher made copies of the GFP gene that he distributed to other scientists.

Martin Chalfie, a biologist at Columbia University, New York, N.Y., read Prasher's article with great interest and called him up to receive a copy of the GFP gene. Then he inserted the GFP gene in bacteria. Within one month, Chalfie and colleagues saw a glow through the microscope that proved that GFP could indeed be inserted into a living organism.

"I was ecstatic!" Chalfie says. "The very first experiment gave us fluorescent bacteria. By putting GFP into bacteria, we demonstrated that it didn't need anything else from the jellyfish to make it work."



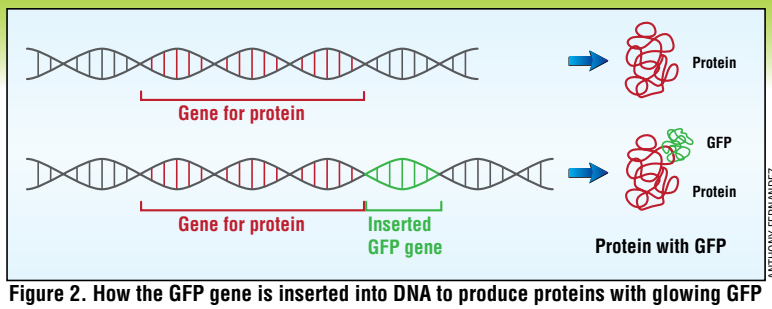
COURTESY OF MARC ZIMMER, HTTP://WWW.CONNCOLL.EDU/CCACAD/ZIMMER/GFP-WW/

Figure 1. Jellyfish contain an umbrella with light-emitting organs along the edge of the umbrella. Inset: In the presence of calcium (Ca^{2+}), the bioluminescent blue light produced by aequorin is absorbed by a green fluorescent protein (GFP), which then emits fluorescent green light.

Also, in these animals, the fluorescent proteins emitted a range of colors, including cyan, green, yellow, and red. "The key finding was a protein that emitted red fluorescent light, which we called the red fluorescent protein" Lukyanov says. "This protein opened up new possibilities for looking inside living cells and living animals, because red light penetrates through animal tissue much deeper than green."

Several years later, Lukyanov's team also found fluorescent proteins in tiny, nonbioluminescent crustaceans called copepods off the coast of South Carolina. Curiously, because of their well-developed eyes, copepods were the first known animals that can actually see their own fluorescent proteins

In 1994, Roger Tsien, a professor of pharmacology, chemistry, and biochemistry at the University of California, San Diego, and Howard Hughes Medical Institute investigator, modified the GFP gene to produce new GFP proteins called mutant GFP proteins that emitted brighter light. Then he created other mutant GFP proteins that emitted other colors, such as blue, yellow, and cyan. This allowed researchers to track more than one protein at a time by attaching different GFP proteins to different proteins inside the cell.



ANTHONY FERNANDEZ

Figure 2. How the GFP gene is inserted into DNA to produce proteins with glowing GFP attached to them.

In September 1998, Sergey Lukyanov, a molecular biologist at the Russian Academy of Sciences, and colleagues discovered fluorescent proteins in non-bioluminescent corals. Unlike ostracods and jellyfish—which first emit bioluminescent light, which is then converted into fluorescent light—these corals only emit fluorescent light.

Preventing plant diseases

Scientists can track plant diseases with fluorescent proteins. Jeanmarie Verchot-Lubicz, a plant virologist at Oklahoma State University, Stillwater, and colleagues are using fluorescent proteins to understand how viruses infect plants. By looking at how a virus called potato virus X infects potatoes, they expect to find ways to prevent viruses from infecting other crops and better understand how viruses cause animal and human diseases in general.

Verchot-Lubicz and her team attached a fluorescent gene to viral genes, so that viral proteins were produced with a fluorescent protein attached to them. Then, by using a microscope, the scientists tracked the movement of the viral proteins as they moved inside plant cells.

"Using fluorescent proteins has been extremely useful," Verchot-Lubicz says. "This is the only way we can see viral proteins moving inside plant cells while they are causing infection. If we don't use fluorescent proteins, we can only look at cells after they have been infected. Here, we can see live everything from the moment the virus enters a cell to how it spreads throughout neighboring cells."

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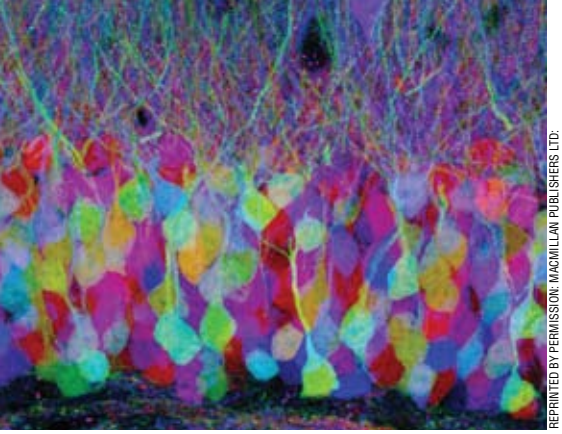

Figure 3. Section of the brain of a "Brainbow mouse" in which cells produce different amounts of fluorescent proteins.

This research has led to the first evidence that, after a potato virus X enters a cell, it uses small cavities called vesicles to carry proteins to the surface of the infected cell. Then, the proteins move across tiny tunnels that connect the infected cell to its neighboring cells, causing these cells to become infected as well.

Verchot-Lubicz's team is now trying to determine what is inside the vesicles and how these vesicles are carried to the cell surface. This information could help scientists develop antiviral drugs that would destroy the vesicles' viral proteins or prevent the vesicles from leaving an infected cell.

Helping to cure brain diseases

One promising application of fluorescent proteins is in research to understand brain diseases. By using fluorescent proteins, scientists at Harvard University have recently developed a way to understand how brain cells interact with one another.

Jeff Lichtman, a professor of molecular and cellular biology at Harvard University, Cambridge, Mass., and colleagues inserted yellow, cyan, and red fluorescent proteins inside the DNA of brain cells in mice, so that each cell produced enough of these proteins to glow. "If you look at a brain tissue under a microscope, it looks like a jumble of cells that cannot be easily distinguished from one another," Lichtman says. "So we decided to use fluorescent proteins to give each cell a different color."

The scientists inserted the genes for the yellow, cyan, and red fluorescent proteins inside the DNA of brain cells in mice, so that each cell produces enough of these proteins to glow. Each cell glowed in a different color based on how many yellow, cyan and red fluorescent proteins were produced in that cell. This way, the scientists were able to produce a mouse brain in which cells glowed in nearly 90 different colors. The scientists called these mice "Brainbow mice" (Fig. 3).

The distinct colors of Brainbow mice can help researchers see individual cells and sort out how they connect with one another. By comparing brain samples from healthy mice with those of mice in which diseases are induced, the scientists hope to better understand what goes wrong in people with debilitating diseases such as Alzheimer's and Parkinson's diseases.

Scientists at the Albert Einstein College of Medicine of Yeshiva University, New York, N.Y., are using fluorescent proteins to study a form of dementia that occurs in about 20% of people infected with HIV, the virus that causes AIDS. The scientists, led by Harris Goldstein, director of the Einstein-Montefiore Center for AIDS Research, bred mice in which cells from

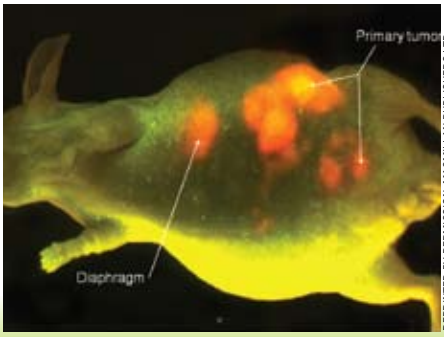

Figure 4. Cancer cells that express red fluorescent proteins are visible in this mouse as they spread from the pancreas to other parts of its body.

their immune system contained both the gene that makes HIV and the GFP gene. This way, not only were the immune cells infected with the HIV virus, but they also glowed green.

By following the movement of these cells in the mice, the scientists showed that these cells went through the brain, thus infecting it too. This discovery was unexpected since these immune cells cannot go through the brain when they are not infected with HIV. These findings shed some light on why some HIV patients develop dementia and may lead to the discovery of drugs that prevent HIV- infected immune cells from getting into the brain.

Battling cancer

Perhaps the most important medical application of fluorescent proteins is its use in the study of cancer. Hoffman, the professor of surgery working on cancer cells in mice, is also the founder and CEO of AntiCancer Inc., a company that develops imaging technology and imaging equipment based on fluorescent proteins. AntiCancer Inc. also sells this equipment to scientific laboratories around the world, making the use of fluorescent proteins widely available.

Thanks to his technique, Hoffman and colleagues have seen how cancer cells migrate in blood vessels and how they grow aggressively to form colonies. The scientists also observed with some detail how cancer cells bind to healthy cells—maybe to infect them or to protect themselves from the immune system—and how cancer cells exchange DNA.

Hoffman and colleagues also discovered that a cancer chemotherapy drug called cyclophosphamide could stimulate the growth of cancer cells in the mice, which was opposite to expectation and suggests that certain approaches to chemotherapy should be modified.

"With this technology, we can expect to discover new classes of drugs for cancer," Hoffman says. "Not only can we see cancer cells move and spread in the body, but we can see how drugs affect them or neighboring cells, which allows us to design better drugs that target cancer cells more efficiently.

In research labs all around the world, fluorescent proteins are glowing brightly, casting a rainbow of light and a glimmer of hope for people suffering from diseases.

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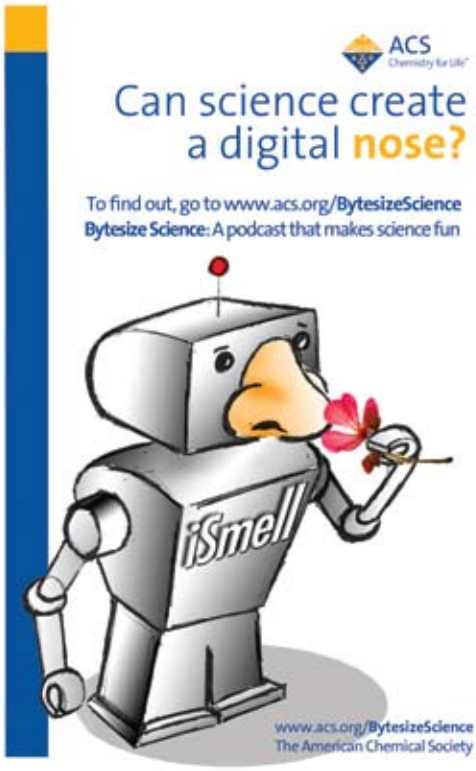
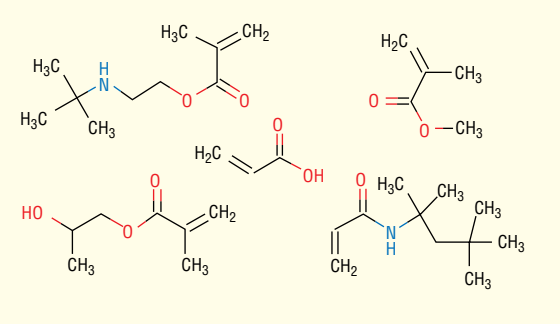


Correction:

An error occurred in Figure 4, p.16 of the October 2008 issue of *ChemMatters*. The correct figure is on the right.



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