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TEACHERS!

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CM Puzzler

For what invention is Alfred Nobel, the originator of the Nobel Peace Prize, famous?

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COVER PHOTO BY MIKE CIESIELSKI AND COREL PHOTODISK

Question From the Classroom

By Bob Becker

Q. How are new pennies different from old pennies?

A. 1982 was a big year for the ordinary U.S. penny. That was the year the recipe changed. Pennies minted after 1982 are almost pure zinc, with a thin electroplated coating of copper to make them look just like the old ones.

Why zinc and not some other metal? Take a look at the Periodic Table and you'll see that zinc and copper are close in atomic weight. Just imagine how lightweight an aluminum penny would feel in your hand! But zinc has an important advantage over both copper and aluminum. It's cheaper. The change in the penny recipe saves the United States millions of dollars each year. Without reading the dates, is it possible to tell new pennies from old, pre-1982 pennies? As a matter of fact, you can have some fun with this. Here is a coin trick to try out on your friends.

What's in a date?

Hand your friends a bandana and two pennies minted in different years, say 1979 and 1993. Have them use the bandana to blindfold you, and then pick out one of the two pennies. Instruct them to shake it by your ear, first left, then right. Next, tell them to scratch the surface—first heads, then tails—and allow you to smell it. Then tell them to drop it on a table top three times from a height of 30 centimeters, telling you whether it feels warm or cold as a result. After *carefully* thinking about *all* of this information, you announce the date on the penny.

Here's how it works. The only part of the whole routine that means a thing to you is the dropping of the penny on the tabletop. But before the session with your friends, you'll need to do a practice session using the same tabletop and some old and new pennies. Listen carefully. You'll hear the difference. Pennies minted before 1982 are almost pure copper (about 5% zinc was alloyed in to make them more durable). When these older pennies are dropped, they make an audible, higher-pitched ringing noise. But the newer pennies lack this resonance. When dropped, they make a hollow, duller sound. Just remember. When you perform the trick, your skill will be much more baffling if you include all the other distracters. That way, the audience has no idea how you are distinguishing the old and new pennies.

Now, amaze your friends with another trick. This one is based on a property shared by old and new pennies.

Heads or tails?

This time, a friend balances a penny, old or new, on its edge on some smooth level surface such as a table or countertop. You are blindfolded or turned away. Your friend strikes the table as you pretend to listen very carefully. As the penny falls over onto its side, you pro-

(Continued on next page)

claim, "That sounded like heads." Sure enough, you are right!

Here's how it works. The edge of a penny is not quite perpendicular to the face. It's angled a tiny bit. In other words, if you were to cut a penny right down the center, the cross section might appear to be a perfect rectangle, but it is actually more of a trapezoid with the tails side bulging out a bit more than the heads side. This shape enables the coins to fall more freely out of the coin press during the minting process. But this shape also causes an edge-balanced penny to be leaning very slightly toward the tails side. As a result, it has a much better chance of landing *heads* up when it falls.

A variation on this trick would be to balance 10–20 pennies, all next to each other with different orientations. Then yell, "HEADS" as you pound down on the table. To your friends' amazement, nearly all the pennies follow your command!

Of course, the tricks only work once or twice. After that, your friends will probably figure out that edge-balanced pennies tend to land heads up.

ChemHistory

The Explosive History of Nitrogen

By Tim Graham

COURTESY OF THE MOORE MEMORIAL PUBLIC LIBRARY, TEXAS CITY, TEXAS

April 16, 1947. It started with a small fire on the S.S. *Grand Camp*, a French cargo ship anchored off Texas City, TX. The ship had recently taken on 2380 tons of ammonium nitrate (NH_4NO_3) fertilizer.

Early efforts by the crew to extinguish the fire were unsuccessful. The fire soon raged out of control. At 9:12 a.m., the ammonium nitrate exploded, sending the 7200-ton ship 20 feet in the air—the first of a series of catastrophic events. Burning debris reached surrounding oil refineries and chemical plants. A 15-foot tidal wave caused two other ships anchored in the harbor to collide. Both were soon ablaze. One of impacted vessels also contained ammonium nitrate. By the time the last flame had been extinguished, 576 people were dead and Texas City was in ruins.

PHOTODISC

Before 1850.

By the mid-1800s, much research on potential explosives had already been done, most of which focused on nitrating solid substances that contained carbon…wood, coal, etc.

1846. Nitroglycerin

is developed by the Italian chemist Asconio Sobrero. Believing that organic liquid substances might show more promise than solids, he nitrated glycerol. The resulting oily yellow liquid, called nitroglycerin, was a powerful explosive that was quite sensitive to shock. But he failed to develop a controlled and effective way to ignite it.

1863. The blasting cap

is invented by Alfred Nobel as a means for exploding nitroglycerin. A blasting cap is a smaller primary explosive that is used to initiate the larger explosion. Nobel placed the nitroglycerin in an insulated container, added a gunpowder primer with safety fuse, and sealed the entire container. Moments after the fuse was lit, the gunpowder cartridge would explode and this, in turn, created enough energy to detonate the nitroglycerin.

1863. Trinitrotoluene,

or TNT, is discovered to be a powerful explosive by the German chemist J. Wilbrand. It proves to be too expensive to manufacture in large quantities.

April 19, 1995. It was one of the most devastating acts of domestic terrorism ever to hit our nation. A truck loaded with roughly two tons of a mixture of ammonium nitrate fertilizer and fuel oil was detonated with a blasting cap on a street just outside the Alfred P. Murrah Federal Building in Oklahoma City, OK. A total of 168 people, many of them children, lost their lives. In 1997, two U.S. citizens, Timothy McVeigh and Terry Nichols, were convicted. McVeigh was sentenced to death and executed on June 11, 2001. Nichols is serving a life sentence.

AP PHOTO LIBRARY

Ever since Alfred Nobel, the founder of the Nobel Peace Prize, developed a process to make dynamite in 1867, explosives have played a key role in both peace and war.

© THE NOBEL FOUNDATION

Today, when we think of explosives, substances like TNT (trinitrotoluene) and nitroglycerin come to mind. But ammonium nitrate? That's just a simple fertilizer! What is it about this simple inorganic compound that can cause it to react so violently? As you probably guessed, the answer is in the chemistry.

All explosions share some features. They all involve the rapid and violent release of large amounts of energy from a confined region of space. Particularly true for chemical explosions, they often involve the rapid expansion of gases generated during the explosion itself. Chemical explosions like those in Texas City and Oklahoma City are accompanied by a loud sharp report, flying debris, heat, light, and fire.

An explosive is a chemical compound or mixture that does the job. The explosive decomposition of nitroglycerin illustrates several features common to explosions:

$$4\ C_3H_5N_3O_9\ (l) \rightarrow 6\ N_2\ (g) + 12\ CO_2\ (g) + 10\ H_2O\ (g) + O_2\ (g) + \text{energy}$$

nitroglycerin

First, the reaction is exothermic, meaning that it releases energy. Second, it produces several gaseous products, all of which expand as the released energy raises the temperature. Third, even though the equation doesn't show it, the reaction is very rapid—once underway, all the energy is released in a very short time. Finally, the reactants include the element nitrogen.

Why do so many explosives contain the element nitrogen? Look at the products of explosive reactions and you'll find the same gas showing up over and over—ordinary nitrogen gas, N_2. The irony is that nitrogen gas is a very stable compound at a very low energy state. But when it is formed from reactants that start out in a very *high* energy state, a very large amount of energy is released in the process. Kaboom!

Why do explosive compounds react so rapidly? One way to speed up a reaction is to thoroughly mix the reactants. Mixing allows for immediate contact to occur. You may have read about explosions in flour mills and grain elevators. Even otherwise harmless substances like flour can explode violently if thoroughly mixed with air and ignited by a spark.

1867. Dynamite

PHOTODISC

is invented. Nitroglycerin is a highly unstable liquid likely to explode with the slightest shock. To reduce its obvious hazards, Nobel uses a finely powdered silicon-based absorbent called Kieselguhr to soak up the liquid nitroglycerin—thus, stabilizing the explosive without sacrificing its strength. Later, he replaces Kieselguhr with sawdust and sodium nitrate. He substitutes ammonium nitrate for some of the nitroglycerin to make a new, low-cost explosive, dynamite.

1900. TNT production costs drop.

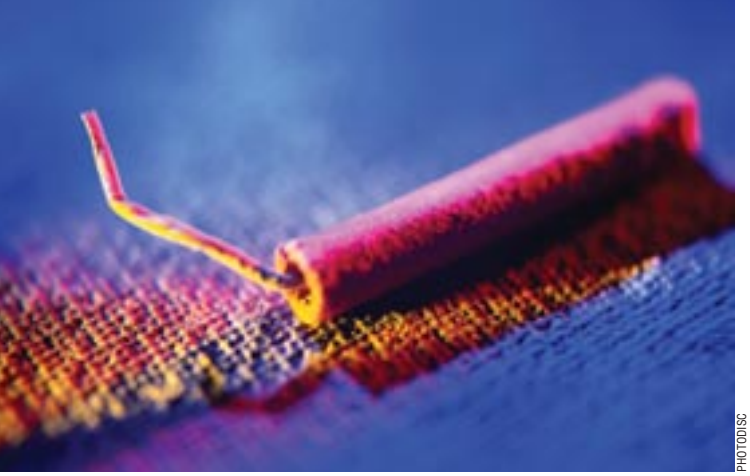
TNT is appreciated as a very stable solid that can be poured and even melted with relative safety.

1914. TNT is used as a weapon in World War I.

TNT's big advantage over dynamite is its capacity for producing shock waves that can rupture the steel on armor-plated vehicles.

1940. World War II

weaponry introduces two new explosives, **RDX** (hexahydro-1,3,5-trinitro-1,3,5-triazine) and **PETN** (pentaerythritoltetranitrate). With additions of wax, motor oil, and other stabilizing fillers, RDX is renamed *Composition Four*, or C-4 explosive. Stable within a large temperature range (–70 ° to 170°F), safe to handle, and easy to mold due to it's plastic-like properties, C-4 is attached to bridge supports, armored vehicles, or the hulls of ships. It is detonated with blasting caps.



PHOTODISC

Ammonium nitrate replaced unstable nitroglycerin to make the low-cost explosive—dynamite.

Molecules of explosive compounds like nitroglycerin or trinitrotoluene take the mixing step one step further. For these compounds all of the reactants are on board the same molecule. Immediate contact is assured.

Let's go back to the Texas City tragedy. What caused the ammonium nitrate in the holds of the ship to explode without the use of some other explosive? Chemists found that the answer was in the bag. The ammonium nitrate fertilizer was packaged in plain paper. The cellulose used to make paper contains a large amount of the element carbon. It was the carbon and ammonium nitrate mixture that reacted to unleash the tragic explosion.

By analyzing the circumstances surrounding the Texas tragedy, chemists began to appreciate the power and potential of ammonium nitrate-based explosives. An effective, relatively safe, and inexpensive explosive called ANFO (ammonium nitrate fuel oil) was developed. And there were no risky transport problems to be solved. To make ANFO, ammonium nitrate and fuel oil were mixed at the blast site.

But ANFO was limited as a commercial explosive. Ammonium nitrate is water-soluble. As it gains water, the energy necessary to initiate its reaction with fuel oil increases to levels making it useless as an explosive. Dupont chemists went to work to produce a form of ammonium nitrate that would detonate even in a wet environment. By adding sensitizers, they were able to detonate the mixture with less-energetic shock waves. Then by adding thickening agents, they produced a syruplike mixture called TOVEX—easy to pour into drill holes at the blasting site.

MIKE CIESIELSKI

Ammonium nitrate, the key reactant in several explosives, is a common ingredient in many plant fertilizers.

It's interesting that dynamite's inventor Alfred Nobel became a pacifist later in life. The man whose name will forever be known as the father of modern explosives dedicated much of his influence and fortune to opposing their use as weapons of destruction.

COURTESY OF THE MOORE MEMORIAL PUBLIC LIBRARY, TEXAS CITY, TEXAS

Tim Graham teaches chemistry at Roosevelt High School in Wyandotte, MI. His most recent article "Luminol—Casting a Revealing Light on Crime" appeared in the December 2001 issue of *ChemMatters*.

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1945. Ammonium nitrate

is manufactured, stockpiled, and shipped to war-torn Europe as an inexpensive fertilizer for enriching depleted farm soil. It's potential explosive power is known, but its stability relative to other explosives seems adequate for production and storage.

1947. S.S. Grand Camp explodes in Texas City Harbor.

Chemists reconsider the stability of ammonium nitrate.

1957. ANFO

(Ammonium Nitrate Fuel Oil) explosive is developed by taking ammonium nitrate "prills" and mixing them with liquid fuel oil to make a "slush". Mixed at the blast site, ANFO is relatively safe to handle.

1988. Pan AM Flight 103

wreckage is found to contain RDX residue. Presumably, as a result of terrorism, the plane crashed in Lockerbie, Scotland, killing all 270 people on board.

Extracting Medicine From Plants

You'll find herbal health supplements in both health food stores and supermarkets. As natural plant materials, they receive little more regulatory attention than salad greens. Should they?

By Carolyn Ruth

Pick up a package of an herbal supplement in your grocery store, and you'll notice that it looks different than the over-the-counter medicines in the next aisle. There are no lengthy fine-print warnings about possible side effects; no cautions about drug interactions; and no big pharmaceutical brand names on the packages.

Herbal supplements are, after all, *natural* products. As such, they are marketed as dietary supplements. Like vitamins, they claim to be *good* for you. But unlike vitamins, the packages often carry claims for curing and easing symptoms—claims that go well beyond our expectations for ordinary foods.

The Mayo Clinic in Rochester, MN, reports that many people choosing herbal therapies for their ailments rely on family and friends for recommendations and advice, probably because there are few published clinical studies to guide their choices.

Most of us assume that there are laws saying that manufacturers must provide evidence for their claims. But when the U.S. Food and Drug Administration (FDA) proposed such a law in 1993, Congress failed to pass it.

Such a law would have limited our access to many herbal supplements. To prove effectiveness and safety, companies would have been required to conduct lengthy and expensive clinical trials on herbal products. Companies would be reluctant to invest in products they would have difficulty patenting. As a result, rather than conducting the required studies, they would be motivated to withdraw the products from the market.

In 1994, Congress passed the Dietary Supplement Health and Education Act (DSHEA), which places responsibility on the consumer for making decisions about herbal supplements. By law, the FDA can pull a product off the market only when there is proof that it poses a dangerous threat to public health and safety.

Herbal traditions

A large part of the world's population still relies on plants and their crude extracts as their only affordable source of medicine. There are many examples. Cloves, for one, have been used medicinally for thousands of years in Southeast Asia. The unopened buds of the clove tree are sun-dried and then used for treating infections including malaria, cholera, and tuberculosis. Digestive discomforts, such as gas, colic, and abdominal bloating are relieved with cloves. Cloves are even useful as a stimulant to strengthen uterine muscle contractions during childbirth.

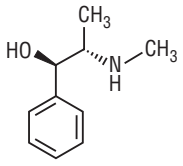
Likewise, many parts of the avocado tree find uses as herbal medicines. Native peoples of Guatemala use the pulp to stimulate hair growth, the rind to expel worms, and the seeds to treat diarrhea.

The aloe vera plant, native to Africa, yields a clear gel from its succulent leaves. The gel, known to be a remarkably effective healer of wounds and burns, has a long history as a skin lotion. Cleopatra was said to attribute her legendary beauty to aloe vera.

Herbal medicines have traditionally provided effective remedies for a variety of human ailments. Their widespread use continues today. Projects in the Dominican Republic and Nicaragua are teaching women how to use the benefits of local herbs within their communities. In Cuba, physicians sometimes prescribe medicinal herbs to compensate for shortages of conventional medicines.

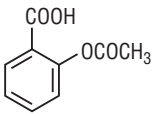
How are herbal medicines, called simply "botanicals" in the United States, different from other medicines? Part of the answer is obvious. They come from plants. But this plant source actually adds to their complexity. A powdered plant product contains complicated mixtures of related chemicals. It may not be clear that any one single molecule is responsible for the activity of the extract. In fact, the most significant characteristic of herbal medicines is this mixture of compounds that presents a variety of possible effects.

Modern or conventional medicines usually consist of individual biologically active molecules. For example, the active ingredient in aspirin is acetylsalicylic acid. Ephedrine relieves asthma and hay fever symptoms. Morphine is a potent painkiller. Although these three pharmaceuticals are considered modern medicines, their history lies in herbal medicine.



Ephedrine

Acetylsalicylic acid was originally developed by modifying the salicylic acid found in the willow (*Salix* spp.) and meadowsweet (*Filipendula ulmaria*) plants traditionally used in Europe. Ephedrine is extracted from *Ephedra sinica*, an herb long used in China. Morphine comes from the opium poppy (*Papaver somniferum*), cultivated in various parts of the world for thousands of years.



Salicylic acid

Modern medicines from herbal remedies

If the medicines aspirin, ephedrine, and morphine were once botanicals, how did they get to be tested and marketed as drugs? Modern drug development and discovery have frequently been stories of the extraction, synthesis, and modification of molecules first found in plants.

One such story is the development of the heart medicine, digitalis. In 1785, the leaves of an ordinary garden ornamental called foxglove (*Digitalis purpurea*) were introduced into medicine when an Englishwoman was successfully treated for dropsy—a condition in which tissues swell with fluid due to a weakened heartbeat.

At first, whole foxglove leaves were dried and powdered, but eventually, the single chemical *digitoxin* was isolated from the leaves. By the 19th century, the pure chemical compound was administered. A less toxic but similar compound, digoxin from another species of foxgloves, replaced digitoxin and is still preferred by many physicians for relieving the condition.

Even better known is the story of quinine. An extract of the bark of various Cinchona tree species had been used since the 16th century for treating malaria. In 1820, the single chemical quinine was isolated from the bark. This drug is still important for malarial treatment.

PHOTODISC

Plant chemicals as starting materials

Sometimes, compounds derived from botanicals are further modified after their initial extraction in a process called *semisynthesis*. Steroids—the category that includes many of our major hormones—are produced cheaply and efficiently from chemicals derived from plant material. Some significant changes in modern society result from the steroids derived from plant material. For example, the sex hormone progesterone now prevents miscarriage in progesterone-deficient pregnant women. Supplies of this hormone were scarce until a related hormone was discovered in plants. American Russell Marker developed a method for converting plant steroids obtained from Mexican yams (*Dioscorea* spp.) to the animal steroids like progesterone. Marker's research eventually extended to the synthesis of other human hormone replacements and supplements, including the progesterone and estrogen-like compounds used as oral contraceptives.

Flowering plant sources of molecules discovered to be biologically active in animals have resulted in the development of approximately 25% of the drugs now prescribed by doctors in the developed world. Despite two centuries of active exploration and research, an estimated 90% of the world's flowering plant species remain to be analyzed for their possible pharmaceutical potential.

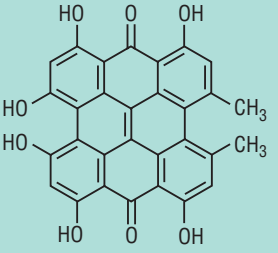
Discovering more medicinally valuable plants is important. Deciding which plants to

PHOTODISC

St. John's Wort

(Hypericum perforatum)

An herbal supplement receiving widespread attention is St. John's Wort—a freely growing field plant whose flowers were used in medieval Europe to heal "down-heartedness". Recent European research has restored this herb to prominence. German doctors prescribe it for patients with mild to moderate depression and, even more remarkably, German insurance companies have been paying for it.



Hypericin

Like many herbal medicines, St. John's Wort relies on the complex interplay of several active ingredients for its antidepressant actions. One of these ingredients is hypericin, which inhibits monoamine oxidase, a body chemical often associated with depression.

Several antidepressant drugs are widely used in the United States and are considered effective. Patients, however, sometimes report unpleasant side effects such as a dry mouth, nausea, headache, diarrhea, or impaired sleep. In part because of these side effects, many affected individuals are trying herbal treatments. St. John's Wort seems to have fewer and less severe side effects than the prescription drugs. In addition, it costs less than most antidepressant medications, and it does not require a prescription in the United States.

Like many herbal supplements or botanicals, however, it may not be as potent or as quick to act as prescribed treatments. And it may actually interfere with other medications. National Institutes of Health research shows that St. John's Wort may reduce the effectiveness of several prescription drugs by speeding up activity in a key pathway responsible for their breakdown. The end result is that blood levels of these drugs rapidly decrease because the body breaks them down faster.

St. John's Wort is thought to negatively affect cyclosporine, a drug used to prevent organ transplant rejection, birth control pills, blood thinners such as Coumadin, some cholesterol-lowering medications, and several other prescribed medicines. Patients should talk to their doctors before taking St. John's Wort or any other herbal medication, especially when they plan to take it in combination with other medicines.

People with mild depression who are not taking conflicting medications can opt to use this herbal medicine. Good judgment is the key. Currently, no U.S. laws restrict its sales.

St. John's Wort is sold as a tea, a tincture, and a capsule. Teas are made with 1–2 cups of flowers per 1 cup of boiling water and drunk three times daily. Tinctures are mixtures of the active ingredients that have been extracted from the flowers with a solvent. The dosage of tincture is 1/4 to 1 teaspoon up to three times per day.


SCIENCE IN A TECHNICAL WORLD © ACS 2001

Both biologists and chemists play important roles in modern drug discovery.

investigate is difficult. One strategy for selecting plants for investigation is to study the ones chosen for medical uses by native populations in a particular ecosystem. Traditional medicines have yielded many important drugs, but this line of research often proves costly and time-consuming.

One effective way to narrow the search for valuable plants is to focus on species biologically similar to ones that have already proven useful. Reserpine, used as a tranquilizer, was extracted from *Rauwolfia serpentina* for years until it was discovered that there were much larger concentrations of this valuable chemical in some biologically related species.

Clearly, there are roles for both biologists and chemists in modern drug discovery. The role of chemists is critical both for the identification of the compounds in plants and for the modifications necessary to improve their usefulness.

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Carolyn Ruth is a chemistry teacher at Harbor Creek High School in Harborcreek, PA. Her article, "Sizing Up Paper", appeared in the April 1998 issue of *ChemMatters*.

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Green cows? Color us surprised.

It's true! Researchers are trying to develop green cows. No, not green-*colored* cows, but environmentally cleaner cows. Cattle, as they process their grassy diet, release a significant amount of atmospheric methane (CH_4)—a greenhouse gas, second only to CO_2 in terms of overall effect. Researchers take that fact very seriously. Most scientists agree that greenhouse gases contribute to global warming.


PHOTODISC

Now researchers believe that they can alter cattle digestion, either by banishing the methane-producing microorganisms from their stomachs or by introducing microorganisms capable of producing alternative metabolic products. Either way, the result is the same —green cows.

And that's not the only surprising development that dairy farmers and researchers have in store. Organic milks are already available at supermarkets. Now, a new line of designer milks is on the drawing board that will boost immunity, improve lactose digestion, and relieve diarrhea. Advances in biotechnology have made it all possible.

Biotechnologists have identified a cattle gene for milk fat synthesis that may one day allow scientists to selectively breed cows for producing low-fat milk. Although the development of genetically modified cows and milk products shows promise, consumer resistance to such products will continue well into the future, the researchers predict.

These and other developments are described and discussed in a special report commemorating the 50th anniversary of the *Journal of Agricultural and Food Chemistry*, a peer-reviewed publication of the American Chemical Society, the world's largest scientific society. The report, appearing in the December 4, 2002, issue, is by Lawrence K. Creamer, of the Fonterra Research Centre in New Zealand.

You can locate the article online. By following these steps, you can access this and many other ACS publications, all of which might come in handy when you need information for a project or a report. First, go to the ACS Web site: www.chemistry.org. Next, go to the "Quick Find" pull-down menu on the left side. Choose "ACS Publications". Here, you'll find many search tools. To find the journal we pointed out, choose the "Journals and Magazines" link on the left. From there, it's an easy find.

NexGen and the color of money

Cows may be turning green, but U.S. currency is about to take a different turn. As early as the fall of this year, the Department of the Treasury's Bureau of Engraving and Printing will launch some design changes in our $100, $50, and $20 bills.

The new series, called "NexGen", will stick with the same sizes, portraits, and images to preserve our familiar U.S. appearances. But you're going to notice some interesting and obvious differences.

The NexGen designs will include some new background colors. While the developers don't consider color alone to be a key security feature, its use will allow them to add more complexity to the designs. The idea is that the more complicated a bill's overall design, the harder it becomes to make counterfeit copies. There's another advantage to tinted money, and it makes you wonder why they never thought of it before. With color-coded currency, it will be easier to tell one denomination from another. Especially, older adults with failing eyesight should appreciate this feature.

For more information about NexGen currency and the history of U.S. money, visit the Web site of the Bureau of Engraving and Printing at www.moneyfactory.gov.

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