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COVER PHOTO BY SONYA SENKOWSKY/ALASKAWRITER.COM
EAGLE STUDENTS LISTEN AS PAUL SCHUSTER TALKS ABOUT
WHAT THEIR SAMPLING HAS ACCOMPLISHED.

Question From the Classroom

By Bob Becker

Q. At one point in the movie Terminator 2, an unstoppable, metallic, killer cyborg is frozen by liquid nitrogen and shatters when shot. My chemistry teacher accidentally spilled a drop of liquid nitrogen on her forearm during a demonstration and it didn't freeze. How is that possible?

A. Generally speaking, exposing one's body parts to liquid nitrogen is not considered "good lab technique". Liquid nitrogen is cold! It boils at a frigid –196 °C.

The reason your teacher was lucky enough to get away with it, while Mr. Metallic Villain (The T-1000) was not, has a lot to do with some of the unique properties of water, of which your chemistry teacher is mostly made.

To begin with, water has an extremely high specific heat capacity: 4.18 J/g°C. This means it takes over 4 joules of energy to raise the temperature of 1 gram of water by 1 degree Celsius. In comparison, a fluid metal such as mercury (The T-1000 looked a lot like mercury when he had no shape) has a specific heat of only 0.140 J/ g·°C. This generally means that, gram for gram, compared to mercury, it takes about 30 times more energy and about 30 times longer to heat up (or cool down) a given sample of water. What's more, water's heat of fusion is very high: 334 J/g. This is the amount of heat that must be removed to get a gram of water at its freezing point to turn completely to a solid. Mercury's heat of fusion is only 11.8 J/g, again, about 1/30 that of water. So, not only is water a lot more resistant as far as temperature changes go, it's also more resistant to phase changes.

PHOTODISC

Will these droplets of mercury join together to form a killer cyborg? Probably not.

Indeed, your chemistry teacher is also covered with water. That's right. Believe it or not, your teacher sweats, just like you do, especially when she is about to put her extremities in harm's way. And this layer of water helps to protect her by giving up its energy (reluctantly) to the liquid nitrogen.

Furthermore, think of the temperature difference (~230 °C) between your teacher's arm and the liquid nitrogen. Because the liquid nitrogen is already at its boiling point, it immediately, and very vigorously, boils. In so doing, nitrogen gas pushes away the liquid nitrogen from her skin. A water droplet skittering around in a hot skillet is similarly floating on a cushion of steam. This means that if a drop rolls off her skin and doesn't get trapped in her clothing, direct contact between the liquid nitrogen and her skin is minimal. And if the direct contact is minimal, then so is the heat transfer.

Did your teacher put on a nonabsorbent lab apron before she performed her daring demo? I hope so. The material safety data sheet (MSDS) for liquid nitrogen warns of the risk of clothes getting splashed in the super-cold fluid, especially given the liquid nitrogen's tendency to boil vigorously and erupt out of its container when warm objects are placed in it. If liquid nitrogen gets caught in clothing, it can flash-freeze skin cells and cause frostbite. The frozen tissue is at first "painless and appears waxy with a possible yellow color", but as time passes, the tissue "will become swollen, painful, and prone to infection when thawed." Ouch!

Your teacher was probably demonstrating that liquid nitrogen can freeze and alter the properties of once-flexible items. But does everything become brittle when cooled down to extremely cold temperatures? The answer: Not necessarily. Flowers do, but that is because of their high water content. When


ARTVILLE/PHOTODISC

MIKE CIESIELSKI

Cooled to –196 °C, a once-flexible tube will shatter when struck with a hammer.

racquet balls and rubber bands are cooled way down, they become as brittle as ceramic. Polymers have *a glass transition point*, a temperature below which their molecular chains are unable to move around each other freely. Without this freedom of movement, the material loses its flexibility and becomes rigid.

And what about the metallic T-1000? A piece of copper wire is quite pliable because its atoms are arranged in neat rows that can slide past one another as the wire is bent or hammered out. These are known as *slippage planes*. They allow the metal to be flexible even at very low temperatures. Since the T-1000 was quite flexible, I imagine he probably shouldn't have shattered. But not all metals behave this way, and sometimes we do not want metal objects to be too flexible. If steel nails, for example, were as flexible as copper wire, your house could probably never have been built. One way to take out the flexibility is to add intentional impurities— atoms of a different size, such as carbon, that interrupt these slippage planes and act to make the metal less flexible. High-carbon steel is an example of such a "hardened" metal. Nonetheless, at room temperature, the movement of the atoms provides sufficient space around these impurities to allow a small degree of flexibility. Otherwise, the nail would shatter when it was struck. Low temperatures slow the atoms down and thus take away this extra space and the resilience it provides.

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Under anesthesia, you are more than asleep; you're unconscious. But what is anesthesia? Do we really know how it works?

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They reduce fevers and swelling. They're also good analgesics. How do drugs like aspirin and ibuprofen provide relief for so many symptoms?

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The properties of many substances change drastically when subjected to temperatures below –150 °C. Everyone knows that chemistry is really cool, but cryogenics takes it to the extreme!

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Although it's gotten safer over the past 100 years, coal mining is still a dangerous occupation. Explosive coal dust and methane gas are major hazards.

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TEACHERS!

FIND YOUR COMPLETE TEACHER'S GUIDE FOR THIS ISSUE AT www.chemistry.org/education/chemmatters.html.

The Aspirin Effect: Pain Relief and More

It's a beautiful summer day–sunny, breezy, not too hot. You and your friends are tossing a Frisbee in the park. You run to catch it and step into a hole. You feel your ankle twist and you collapse into a heap. You pick yourself up, but there is something really wrong. You cannot put any weight on that foot–not without major agony. A few hours later, after the X-ray has shown nothing is broken, you are sitting at home with your foot propped up with an ice bag on an ankle that looks like it belongs to Dumbo, the elephant. Your doctor says you'll be fine in a week or two. He recommends rest, ice, elevation, and maybe some aspirin or ibuprofen. No more summer fun for you for a while! Well, there's always cable, you think.


PHOTOTDISC

MIKE CIESIELSKI

By Doris R. Kimbrough

But before you settle into channel surfing, think about that bottle of aspirin or ibuprofen. How can one little medicine do so many things? It relieves your pain, reduces the inflammation (swelling), and generally makes you feel better. You take it when you have a fever, and maybe your grandmother or grandfather takes it to prevent heart attacks or relieve pain from arthritis. Is it one single chemical or a mixture of several substances? Aspirin, ibuprofen, and other nonsteroidal anti-inflammatory (NSAI) drugs are each single molecules from a class of chemical compounds called *arachidonic acid pathway inhibitors*. Arachi-who? Let's back up and take a closer look at the arachidonic acid pathway and the wonderful world of prostaglandin synthesis.

Prostaglandins

Prostaglandins are a very important member of the lipid family of molecules in the human body. Lipids are all the molecules that are soluble in nonpolar solvents (like oil) and insoluble in polar solvents (like water). Lipids include fats, oils, steroids (like cholesterol), and prostaglandins. Prostaglandins are made of carbon, hydrogen, and oxygen and have a five-membered ring, two carbon chains, and assorted double bonds and other groups. They have wildly descriptive and romantic-sounding names like: PGG$_2$, PGF1α, and PGI$_2$.


ARTVILLE

Prostaglandins are extremely powerful chemicals and do their jobs at very low concentrations. They mediate some rather uncomfortable and unpleasant bodily processes. They are involved in pain, inflammation (swelling), fever, blood pressure regulation, menstrual cramps, labor, blood clotting, and asthma attacks. Furthermore, biochemists are, even now, hard at work discovering new prostaglandins and trying to determine what they do in the body.

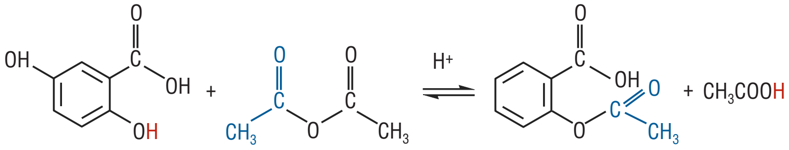
Every single prostaglandin molecule in your body comes from the same “parent molecule”, a long-chain fatty acid called arachidonic acid. The body converts arachidonic acid to the first prostaglandin, PGG$_2$ with the help of a well-named little enzyme called *cyclooxygenase* (COX$_1$ for short). It forms a ring (the “cycle” part) and adds an oxygen molecule, O$_2$. See the “oxygen” in the middle of the word?

From PGG$_2$ the body makes PGH$_2$, and then the party starts. At this point, the chain branches, and PGH$_2$ is converted into a wide variety of prostaglandins. Your body turns on and off various enzymes that can act on PGH$_2$, depending upon which prostaglandins it needs. After you shoved your foot in that hole, several prostaglandins from PGH$_2$ were synthesized and pressed into service. You have them to thank for the pain and swelling, as well as the clotting of the various blood vessels you broke that will make your ankle ultimately turn a variety of interesting shades of blue, purple, and green.

What is the benefit of the body synthesizing chemicals that make you so miserable? In a backward way, it is a self-protective measure. The pain reminds you that you are injured so that you take it easy on that ankle and give it a chance to heal. The blood is clotting so that you don’t bleed to death, and the inflammation increases the metabolism around the injury, which starts the chemical processes that will ultimately result in healing. Fine, you say, but my ankle really hurts and I don’t want to feel so miserable. Well, that’s where the NSAIs come in.


MIKE CIESIELSKI

NSAI drugs are in many pain relief products.

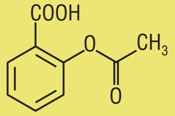


Preparation of aspirin.

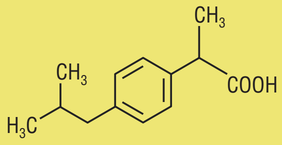
NSAI drug history

Let’s go back to the Middle Ages. You are a countess in England, and you are suffering from a crippling headache. Or, if you prefer, you are a knight in shining armor with a wicked black eye from a fight with a dragon. Either way, your servant brings you a draught of willow bark extract. “Please milady (or milord), drink it! You’ll feel better!” You grimace, close your eyes tight, and down the awful concoction. It does make you feel better even though it tasted dreadful and made your stomach a bit queasy.

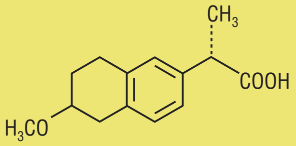
What was in that willow bark extract? Willow bark contains a chemical called salicin, which is converted to another chemical called salicylic acid in your body. Salicylic acid is one of the many compounds that act as NSAIs; however, it is extremely irritating to the stomach and mucous membranes.



Acetylsalicylic acid (aspirin)



Ibuprofen



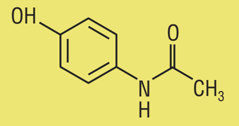
Naproxen

In 1897, a German pharmacist and chemist named Felix Hoffmann, working for Bayer, found a solution for that bitter pill and acetylated salicylic acid, meaning that he replaced the hydrogen on the –OH groups with a -C(O)CH$_3$. This compound is called acetyl salicylic acid. This made the drug much more tolerable to the stomach, and the Bayer Company quickly marketed the miracle, pain-relieving, fever-lowering, anti-inflammatory drug under the trade name, “Aspirin”.

Another player on the pain and fever relief scene is acetaminophen, the active ingredient in Tylenol. Even though it was first synthesized by Harmon Morse in 1873 and used medically in 1893, acetaminophen didn't really get medically popular until after World War II. However, acetaminophen does not relieve as many symptoms as aspirin (more on that later). The 1970s saw the discovery of ibuprofen and naproxen. These two drugs were found to be as effective or more effective than aspirin and even less irritating to the stomach. We are lucky to live in a time when there are a variety of ways to effectively treat pain. So how do all these molecules work in the body?

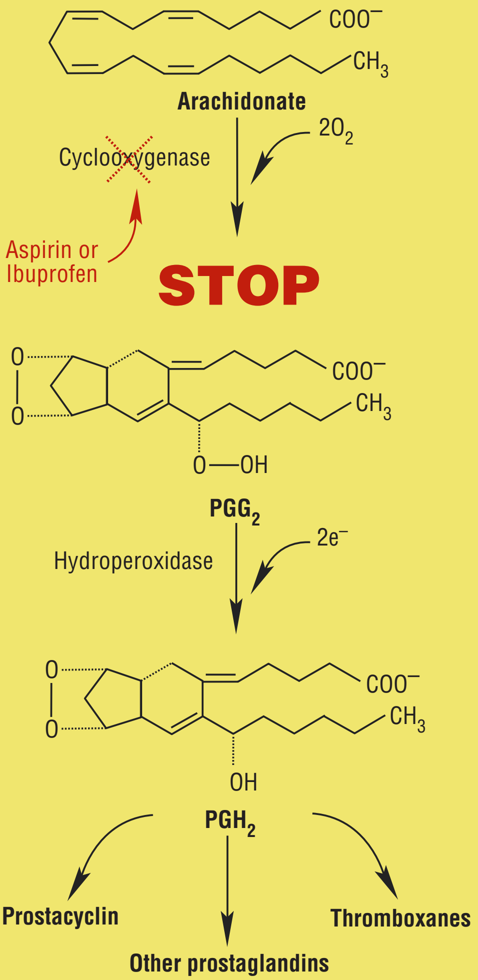
The mechanism

Aspirin, ibuprofen, and other NSAIs inhibit the arachidonic acid pathway early in the process—at the cyclooxygenase step to be precise. These chemicals are called *competitive* inhibitors. They compete with the arachidonic acid for cyclooxygenase, binding with it so that the arachidonic acid cannot. If the enzyme is busy with the NSAI, it cannot do its job on the arachidonic acid. Voila! You stopped the first step, and the whole process shuts down. The prostaglandins responsible for pain won't get made, nor do the ones for inflammation, fever, or clotting. Actually, some still get made, just nowhere near as many as usual. That's why the NSAIs seem to be such wonder drugs—they inhibit the formation of all of the prostaglandins, which have so many widely different functions.



Acetaminophen (Tylenol)

How NSAI Drugs Work



Prostaglandins can trigger unpleasant bodily processes like pain, inflammation, and fever. NSAI drugs, like aspirin, prevent the enzyme cyclooxygenase from catalyzing the conversion of arachidonate to the prostaglandin, PGG_2. This blocks a cascade of biochemical reactions that produce prostaglandins.

PHOTODISC

Some people talk about how "aspirin thins your blood". It doesn't really; it just makes the blood clotting mechanism less effective because clotting is controlled by two prostaglandins. So since aspirin inhibits the formation of those prostaglandins, they cannot form. That is how aspirin helps protect those with heart disease from heart attacks. Ibuprofen is better than aspirin at blocking the action of cyclooxygenase, which is why it is more effective at pain relief and fever reduction.

Some folks are allergic to aspirin or find that it and other NSAIs upset their stomachs. They may take nonaspirin pain relievers, such as the acetaminophen mentioned above as alternatives. Acetaminophen does a good job of relieving pain and also works well on fevers, but it doesn't help with inflammation, nor does it offer the reduced clotting protection for those with heart disease. Why does acetaminophen do some of the things that NSAIs can do but not others? The answer lies in where the acetaminophen inhibits the arachidonic acid pathway. Acetaminophen doesn't inhibit cyclooxygenase like the NSAIs. It works on an enzyme further down the pathway. At this point the pathway has already branched somewhat and the prostaglandins responsible for clotting and inflammation have peeled off. By inhibiting the pathway further down, acetominophen only works on fever and pain.

ARTVILLE

Next time you play the game, "Shipwrecked on a Desert Island and Only Allowed to Have One …." (book, CD, person, etc.), you can pick an NSAI as your one medicine. Most doctors would. So even though a lot of people pooh-pooh the advice: "Take two aspirin and call me in the morning," as a brush-off from the doctor, you can now appreciate that aspirin and all of its NSAI buddies represent some pretty powerful and effective medicinal chemistry!

Doris R. Kimbrough teaches chemistry at the University of Colorado–Denver. Her article "Urine: Your Own Chemistry" appeared in the October 2002 issue of *ChemMatters*.

Coal Mine Safety

PHOTODISC

By Harvey Black

For a few days in July 2002, the safety of nine Pennsylvania coal miners trapped 240 feet below the surface held a horrified nation riveted to the 24-hour television media coverage. When the nine Quecreek miners accidentally broke into a water-filled abandoned chamber, they were effectively cut off from their escape route.

Tension reached the breaking point when mining engineers and geologists armed with old maps, their knowledge of the mines, and their Global Positioning Satellite devices gave the word: "Dig here." There was no margin of error. Time loss and the risk of flooding the Quecreek miners' only place of refuge loomed as the deadly outcomes of digging the wrong shaft. They got it right. On July 28, nine exhausted miners were hoisted to the surface where they were embraced by their families. An entire nation breathed a collective sigh of relief.

For a time, public interest and the media lingered on the spectacle. Good questions arose about our national dependence on coal and the accompanying safety risks that go along with its use. Many of these questions are still waiting for answers.

Story of black diamonds

Let's start with one that is relatively easy to answer: What is coal? Most of us think of coal only in terms of deep mines or in terms of stripped-off mountaintops. We think of huge machines, hard labor, and all of the hazards that go along with an industry that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has figured heavily in our nation’s history.

But the story really starts long before the first settlers arrived. It starts with land and plants that look nothing like coal and the underground seams where it is found today. Think of the Everglades in Florida or the Okefenokee Swamp in Georgia. Coal begins to form in swamps and bogs like these.

Geologist Glenn Stracher of East Georgia College defines coal as rock formed from the remains of plant materials. “Anything that comes from a plant can go into the process of making coal,” he says. On a much smaller scale, animal remains are also included.

As the growing season passes, plants growing in swampy areas die and their remains fall into the water. There, they start to decompose, but do so very, very slowly. That’s because in the still water of swamps and bogs, there is not enough dissolved oxygen to meet the requirements for most decomposers—bacteria and fungi.

“More material dies and falls in on top of that previous material, and more [organic remains] falls on top of that. So what you started out with initially gets buried deeper and deeper in the swamp as time goes by,” explains Stratcher. He notes that coal in Pennsylvania can be between 200 and 300 million years old. The term *fossil fuel* is applied to fuels like coal that trace their origins to these long-dead plants and animals preserved in the earth.

Coal formation goes through a number of stages. The initial stage is peat—a loose brown collection of plant material. Over time, successive forms of coal are lignite, bituminous, and finally anthracite. Each successive form contains a higher percentage of carbon, releasing more heat for a given weight when burned.

Actually, each successive form represents organic material buried deeper in the earth over a longer period of time. As overlying sediments pile up, both the temperature and the pressure increase. About 3–7 feet of compacted organic matter transforms under temperatures ranging from 100 °C to 200 ˚C to yield about 1 foot of bituminous coal—the most common form in the United States.

Our dependence on coal

Worldwide, people have been digging coal out of the earth for more than 1,000 years. Coal mining in Pennsylvania dates back to colonial America, but both here and elsewhere, the demand for coal soared during the 19th century as the Industrial Revolution got under way.

Coal may not be the first thing you think of as you hit a light switch or open your refrigerator, but more than half of the energy consumed in the United States today is traced to coal fuel. Today, coal is not often burned directly in furnaces to provide heat for buildings. But it remains the major source of energy for creating steam. Hot steam turns turbines in power plants, and electricity is the result.

Although residents of the northeastern states had an opportunity to ponder life without electricity when the power grid went down last June, few of us can imagine anything longer than a temporary blackout. Health, safety, transportation, manufacturing, entertainment—in short, life as we know it is dependent on a stable power supply. And underlying that power supply is coal.

As Barry Commoner, an environmental activist and author once put it, “There is no such thing as a free lunch.” What is the real price of our dependence on coal? We’ve already noted how tragedy can strike in the mining industry. Are there other risks?

Coal is risky business

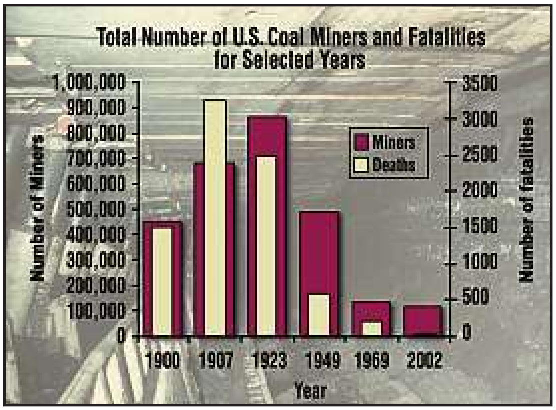
Burning coal releases a range of pollutants into both air and water. Most notable among these pollutants are oxides of sulfur and nitrogen—both causing air pollution and the production of acid rain. The burning of coal may also release mercury into the environment, which collects into waterways to be ingested by fish. Consuming mercury-contaminated fish puts humans at risk for kidney and nervous system damage.

Concentrated pollutants released into the air by burning coal can bring about tragic results. One such incidence was the infamous killer smog that settled on London in December 1952. A long cold spell kept coal fires burning longer than normal, and a weather condition called a “temperature inversion” kept the smoke at ground level. The result was thousands of deaths in four days.

Although no one was killed in 2000 when millions of gallons of gooey, sticky coal mine wastes broke through the walls of an impoundment, several streams in Kentucky were horribly polluted. The wildlife population that depended on the river for food was immediately devastated.

Sometimes the health effects of coal exposure take years to develop. Black lung disease, which is characterized by scarring and inflammation that make every breath a chore, results from years of inhalation of tiny coal particles. Today, one coal miner in 20 has some form of the disease, according to the American Lung Association. Although coal particles can cause a long-term illness, it is methane that can be responsible for more immediate and equally deadly effects.

Methane (CH_4) is the major part of natural gas, in itself a source of fuel. It is released by the lengthy processes that result in coal formation. In coal mines, this odorless, colorless, lighter-than-air gas, is a constant safety concern. With any spark to ignite the gas, methane in concentrations of between 5 and 15% in air readily explodes, explains Stephen Schatzel, a geologist in the National Institute of Occupational Safety and Health (NIOSH), a federal agency that works to make sure conditions on the job are safe.



SOURCE: DEPARTMENT OF LABOR

The number of coal miners and fatalities has decreased sharply over time. Coal mining is still dangerous. In 2002, there were 27 deaths.

To reduce the methane risk, current government mining regulations require that the maximum level of methane be even lower. “In most of the mine workings, it has to be below

1 [percent],” says Schatzel. To keep methane levels at regulation level, fans are installed to move air out of ventilation shafts at very high rates of speed. There are also extensive and powerful ventilation systems to provide fresh air to areas where the miners are working. And three times per hour, mandatory checks are made to see that the methane concentration is no greater than 1%.

And that’s not all. “The mining machinery is required to have detection devices called methanometers on them. The devices shut down the machinery [automatically] at 1%,” he says.

Keeping methane low is critical given the risk of ignition in a mine. “You have a piece of mining equipment that is operating, and it strikes coal or the roof or floor rock, the rock immediately above or below the coal bed—and it produces a spark,” explains Schatzel.

Explosions kill

In what was one of the worst accidents in nearly 20 years, a methane explosion in an Alabama coal mine killed 13 miners in 2001. In China, where thousands of mines are poorly ventilated, methane explosions still kill thousands of miners each year.

Explosions can occur even when methane levels are low. Tiny particles of coal dust suspended in oxygen-rich air can be another potential disaster just waiting for a spark. On April 26, 1942, 1549 people were killed by a coal-dust explosion at Honkeiko (Benxihu) Colliery, China. That was the worst single coal-mining disaster in history, according the *Guinness Book of World Records*. Today, coal dust continues to pose serious risks in China and elsewhere. In May of 2002, 18 miners were killed in an explosion at a coal mine in Wentang township in China’s southern Hunan province.

Despite attempts to regulate gas and particle exposures, Schatzel is concerned that these hazards will increase as new mining methods are developed to dig out more coal in less time. “The more rapid the mining moves ahead, the more gas they [the miners] will encounter because the gas has not had an opportunity to bleed off from the coal. That presents an inherent challenge. The methane control technology really hasn’t changed dramatically from the seventies. So we try at look at new methods,” says Schatzel.

Schatzel and his colleagues are working on a mathematical model to predict the amount of methane that will be released as rapidly operating mining machines slice off huge chunks of coal from mine walls. Figuring this out, he says, is a complex process that takes into account the geologic formation, the depth of the coal bed, the rate of mining, and barriers to gas movement, such as veins of clay. “It’s an ambitious project,” he says.

Coal mines, even inactive ones, are by their very nature hazardous. Abandoned mines present their own set of threats. Certainly, the Quecreek miners found that out as they accidentally penetrated the walls of an abandoned water-filled mine. Abandoned mines can pose hazards above ground too, note professional geologists Robert Turka and Stan Michalski of the geology and engineering firm, GAI Consultants, Inc., of Monroeville, Pennsylvania.

This controlled explosion at a NIOSH facility shows how dangerous methane gas can be if it exceeds safe levels in a mine.

COURTESY OF NIOSH, PITTSBURGH RESEARCH FACILITY

“You create this enormous hole in the ground! Frequently in the old mines, you’ll get a buildup of methane. It’ll move through fractures,” says Turka. There have been instances, though they are rare, in which lighter-than-air methane diffused into homes and exploded.

Mines can also threaten the safety of the environment by releasing acids that drain into streams and groundwater. Acids form when sulfide-rich minerals are exposed to air and water. Pyrite (FeS_2)— particularly common in coal mines—is readily oxidized to form sulfuric acid:

$$2FeS_2\,(s) + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$$

The drainages containing these acids are in the range of pH 0–1 and may contain toxic heavy metals as well, thus posing a potentially lethal threat to aquatic life in ponds and rivers into which they drain.

Although acid mine drainage is a serious problem, it is not an inevitable outcome of coal mining. Ron Graham, a chemist with SGS, Inc., a Swiss-based testing and certification firm, notes that “some rock strata have inherent neutralizing potential.” Calcium carbonate ($CaCO_3$), which is found in some coal mines, dissolves to form a basic solution that can neutralize the acid formed from coal mining.

As an example, he notes that in the major coal mining state of West Virginia, the southeastern part of the state has little problem with acid mine drainage. In this region, calcium carbonate is abundant where coal is mined. In more northern sections of the state, acid drainage is a problem because of the relative absence of neutralizing calcium carbonate.

Coal fuels modern life and the myriad conveniences, services, and devices on which we depend. But, at the same time, coal and its pollutants threaten the environment and even our global climate. On a local level, coal mining may provide not only the jobs on which people’s livelihoods depend, but also the toxins that keep those life spans below the national average.

As the media analyzed the 2002 Quecreek Mine drama, someone speculated that the exhaustive coverage of the potential disaster may have single-handedly killed the future of an industry. They asked, “What kid could watch that drama unfold and still decide to become a miner?” Coal—mining it and consuming it—raises many questions about benefits and risks. These are important questions that will require some deep digging for answers.

Harvey Black is a freelance science writer living in Madison, WI.

Chem.matters.links

Eating bugs made easy

ACS STOCK-THE YELLOW MEALWORM

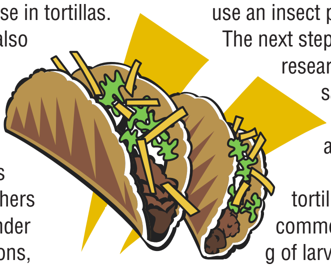
If you watch TV shows like "Survivor" or "Fear Factor", you've probably seen people eating nasty-looking live bugs in order to advance to the next round of competition. The practice of eating insects when big money isn't on the line is called entomophagy.

To be sure, many Eastern and African cultures practice entomophagy—some bugs are even considered delicacies—but for the most part, creepy crawlies are off the dinner plate.

Food chemists are often concerned with developing new food sources to feed a hungry world. If you combine this concern with the estimated 100 trillion insects in the world—some with very high protein content—it becomes obvious that we have a vast, mostly untapped food supply waiting to be exploited.

The fact that bugs are plentiful and nutritious can usually be trumped by a highly reasoned and well-thought-out argument that usually includes the words "eew" or "that's nasty". As a consequence, researchers are looking at ways to make eating insects more acceptable to the Western palate.

Early last year in the *Journal of Agriculture and Food Chemistry*, a group of Mexican researchers reported on the nutritional value of powdered *Tenebrio molitor* larvae and its suitability for use in tortillas.



The larvae, also known as yellow mealworms, are common pests that are found in corn flour. For this study, the researchers grew the larvae under controlled conditions, dried them in an oven, and ground them into a powder. A variety of chromatographic techniques were then used to determine the protein, amino acid, and fat composition of the powder.

Has anyone ever suggested that you eat insect-contaminated food because the insect "adds protein"? In this case, it's correct. The larvae powder is high in protein (58.4%!) and low in saturated fat. It has "small but significant" concentrations of the omega fatty acids, which are usually associated with fish. Omega fatty acids have been shown to increase the concentration of good cholesterol (high-density lipoproteins), while decreasing the concentrations of bad cholesterol (triglycerides).

So the larvae powder is nutritious, but how does it taste?

In the end, no one will want to use an insect powder if it tastes bad. The next step was for the researchers to—shall we say—put their larvae where their mouths are.

Supplemented corn tortillas were prepared with commercial maize flour and 1 g of larval powder. In 36 runs, 18 trained tasting judges were able to perceive either a texture or flavor difference between a larvae-supplemented tortilla and a control 21 times. Perhaps to everyone's surprise, the judges thought the larvae tortilla was **better!** They "perceived better functional characteristics for taco rolling, exceptional mouth-feel sensation, and better taste for the supplemented tortilla."

Don't expect "larvae" tortillas on store shelves any time soon—the authors caution that further work has to be done to assess the protein digestibility of tortillas containing the powder.

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