MIKE CIESIELSKI

LAB ON A STICK

Within two minutes, one tiny strip, with two enzymes and 16 reagents, can perform 10 tests that help diagnose a host of medical conditions.

By Christen Brownlee

Imagine that you have just swallowed a rich and delicious chunk of sweet chocolate cake. Minutes later, carbohydrates from that cake will become glucose, the sugar your cells use for energy. If you're healthy, a hormone called insulin, produced by islet cells in your pancreas, will snatch glucose from your bloodstream and squirrel it away inside your liver and muscle cells in long chains for future use. But if you have diabetes, your body either doesn't make insulin (type I), or is no longer sensitive to its effects (type II), allowing glucose to build up in the bloodstream.

High blood sugar levels can be toxic to many types of cells, leading to poor circulation, kidney failure, blindness, or worse. Normally, the body naturally regulates the amount of insulin and a counter-acting hormone called glucagon to keep blood sugar in check. Diabetics can keep their blood sugar under control by taking insulin or regulating their diets. But there's only one catch—to know how much insulin to take or how to modify what they eat, people with diabetes need a way to keep track of exactly how high their blood sugar levels are.

Researchers struggled for decades to develop a test for glucose in urine that was easy enough for anyone to use. But it wasn't until the 1950s that former American Chemical Society president Helen Free and her husband, Al, developed the dip-and-read test strips called Clinistix. The tests were such an advance that researchers have since combined 10 urine tests—to check for ailments like liver failure, urinary tract infections, and others—onto one plastic stick. It's like having a team of chemists instantaneously at your disposal. For such a simple idea, urine dipsticks have revolutionized diabetes care and modern urinalysis. But just how did the Frees develop this "Lab on a Stick"?

Most people with type 1 diabetes are first diagnosed during their teen years. In the United States, more than 400,000 new cases of diabetes are reported every year.

COURTESY OF HELEN FREE

Helen and Al Free share a moment with a lab rat at the Miles-Ames Research Laboratory in 1948.

A rainbow of tests

Researchers have known for thousands of years that diabetics excrete sugar into their urine—a side effect of overwhelming the kidneys with too much blood glucose. So, in one of the first tests for diabetes, doctors poured urine on the ground to see whether it attracted insects. If insects crowded around the puddle, it meant they were attracted to sugar, a dead giveaway for diabetes.

Although this test was helpful for determining whether a patient had diabetes, it wasn't sensitive enough to detect how much sugar was present in the urine, an indicator of diabetes severity. So, in the early 1900s, researchers developed a method to estimate the level of glucose in urine. Doctors mixed a blue solution of cupric sulfate ($CuSO_4$) into a urine sample, then put in some alkali (strong base) and a complexing agent such as tartrate or ammonia to prevent precipitation of copper(II) hydroxide. Heating the mixture over a Bunsen burner or in a water bath caused any glucose, a strong reducing (electron donating) substance, to react with the blue cupric ions, changing them to copper(I), which precipitates as the orange-brown copper(I) oxide. The extent of the mixture's color change—from blue to green, brown, and red—gave doctors a rough estimate of how much glucose was in a patient's blood. The test was "colorimetric"—it relied on a visible color change to track the presence of a chemical.

This analysis was better than pouring urine on the ground, but not great. It still required special equipment, harsh chemicals, and plenty of know-how to judge the results. In the 1930s, Walter Compton, the doctor whose family helped found Miles Laboratories, developed an improved version of the same test, with a lot of less mess and effort. He made a tablet with cupric sulfate, sodium hydroxide (the strong base), and citric acid, which he dubbed Clinitest. After putting the tablet in a test tube and adding several drops of water, it fizzed like Alka Seltzer. Heat from the reaction allowed any glucose present to reduce the cupric ions, and doctors compared the remaining mixture's color to a chart to determine the urine's glucose level.

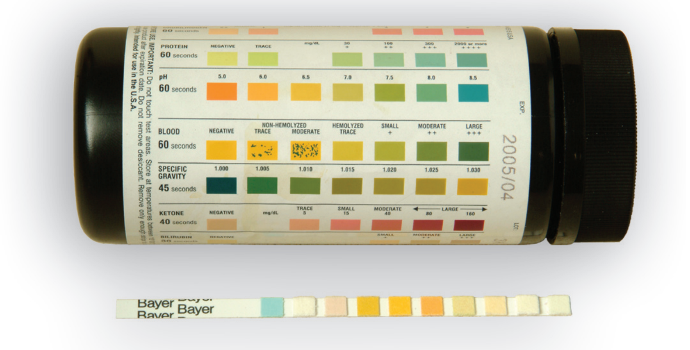
Clinitest was easy enough for some diabetics to use outside the doctor's office, but it still wasn't perfect. Scientists knew that many chemicals, including some drugs, act as reducing substance in urine. So, patients with normal blood glucose levels frequently ended up with false positive results for diabetes. To weed out these bogus results, Helen and Al Free, along with other chemists at Miles Laboratories, developed a tablet test for ketone bodies, a byproduct in diabetics' urine caused by metabolizing fat instead of glucose. The white tablet contained alkali and nitroprusside, $[Fe(CN)_5(NO)]^{2-}$. If a drop of urine turned the tablet purple, the patient had diabetes.

Put it on paper

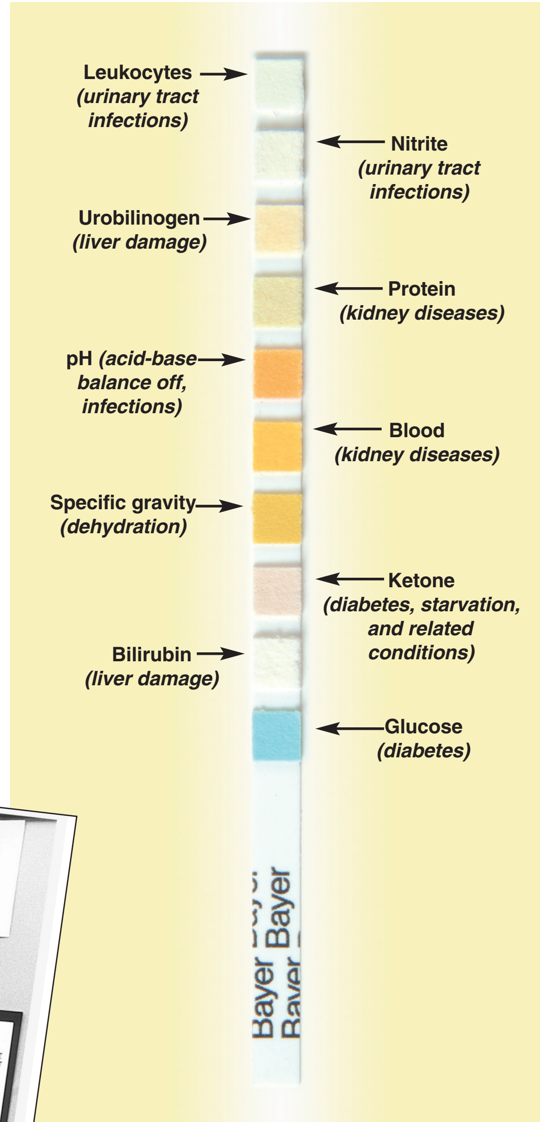
For years, doctors had to perform both tests and a blood test to get an accurate reading of a patient's blood sugar. But in 1953, diabetes diagnostics took a giant leap ahead. A factory owned by Miles Laboratories developed an enzyme called glucose oxidase, which reacted only with glucose. Al Free immediately noticed the potential for a brand new type of glucose test. When glucose oxidase reacts with glucose, it forms two products, gluconic acid and hydrogen peroxide. Testing for gluconic acid proved too tricky for easy analysis, so the Miles chemists focused on a reaction to show the presence of hydrogen peroxide instead. The researchers added peroxidase to react with hydrogen peroxide, as well as a benzidine, a type of chromogen, or chemical that changes color when it becomes oxidized.

COURTESY OF HELEN FREE

The reaction worked like a charm, turning shades of blue with different glucose levels. But the test was still too complicated for most diabetics to use at home. After doing thousands of tests on spot plates and in test tubes, Al had an idea—if the same reagents were on a piece of paper, could you dip it into a urine sample and get the same results? After many more tests, the researchers found that the answer was yes.



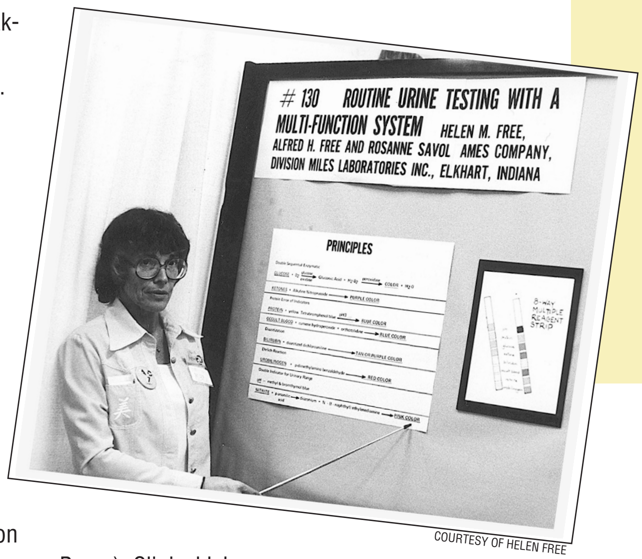
Colorimetric Test. Just like the universal pH paper you might have used in lab, readings for the Multistix-10SG are made by comparing the strip to a color chart on the container.



MIKE CIESIELSKI

Ten tests in one

But the Frees and a hundred other researchers at the Miles Ames Research Laboratory couldn't stop quite yet. They developed a colorimetric paper test for albumin, a plasma protein that leaks into diabetics' urine when their kidneys fail. Since doctors frequently test for glucose and albumin at the same time, they decided to put the two tests on the same paper strip. They later incorporated the ketone test and added colorimetric analyses for bilirubin and urobilinogen, byproducts formed by the breakdown of red blood cells and good indicators for liver failure. Later came tests on the same strip for occult (hidden) blood and protein—two signs of kidney damage—as well as leukocytes and nitrite, signs of a urinary tract infection. The researchers rounded off the strips with reagents for pH and specific gravity, a measure of concentration.



COURTESY OF HELEN FREE

The test strips were so easy to use that they became an instant hit and a big seller for the Ames division of Miles Laboratory (later to become Bayer). Clinical lab personnel simply dipped a strip into urine samples for a practically instant urinalysis, a window into diabetic, liver, or urinary tract health. Today, Bayer sells several varieties of urine dip-and-read tests, including special diabetic test strips, with just glucose and ketone tests, as well as strips called Multistix-10SG, with all 10 tests. Helen Free, still a consultant for Bayer, says that she frequently meets people her work has helped. "They'll say, 'My mother used those strips,' or 'My grandfather did,'" she said. "It's a wonderful feeling, knowing that your work changed people's lives—it gives me shivers when I think about it."

Teachers! Remember the free Teacher's Guide (chemistry.org/education/chemmatters.html) for "Lab on a Stick" student questions, additional information, and activities!

Special interview with Helen Free on the next page!

Q&A With Helen Free

COURTESY OF HELEN FREE

How did you decide to become a chemist?

My English teacher in high school, Miss Johnson, was my role model, and so I was going to be a Latin or English teacher. Then in December, the bombing of Pearl Harbor happened, setting off World War II. In order to avoid being drafted into the army, all the guys went out and joined up for the navy or the air force or wherever, and left college. We had house mothers in our college dorms back in those days, and our house mother's name was Harriet Kline. At dinner one night, she said, "You know, girls, you're going to have to take some science, because we don't know how long this war will last or when the guys will come back." She turned to me and said, "You're taking chemistry, aren't you, Helen? Do you like it? Are you getting good grades?" I answered yes to all of her questions. Then she asked, "Why don't you switch majors?" And I said okay. Boom, it happened just like that. It was a turning point, and such a lucky one that it happened.

How did you meet your husband, Al Free?

I was hired in the control lab of Miles Laboratories, which is now Bayer, in 1944. At the time, we were devising methods to determine the amount of each vitamin in a multivitamin tablet, so each tablet would have the same amount. After we established the method, we were just analyzing vitamins day after day, and it got to be too routine. I kept bugging them to let me go into the research lab, because I thought research sounded like a glamorous thing to do. I was not offered the job in the research lab until 1946, after Miles had expanded, so they had a biochemistry lab. Al Free came from Cleveland to run the new lab. He was a professor of biochemistry at Western Reserve Medical School. My co-workers encouraged me to go interview with Al Free, so that maybe he would hire me. And he did. Two years later, I married the boss—it was one of the smartest things I ever did. We made a team; we were married 53 years, and we just worked together and had a good time the whole time.

COURTESY OF HELEN FREE

Helen Free demonstrates the use of Hemastix and Combistix at a 1940's AMA meeting.

Did you get special treatment because you were married to the boss?

No, in fact, Al bent over backwards not to give me the plush experiments. He gave me experiments working with blood and tears and stools and all that kind of stuff.

How many patents have you held for your research? Did you earn extra money at Miles for each patent?

I've held just seven patents, and there were a whole bunch of people who contributed to each one—it wasn't just Al and me. I made a dollar for each patent. People often will tell me, "Oh, that's terrible!" But I say, well, that's what Miles hired us to do. If you work in a research lab, you're supposed to invent things. That's your job. They pay you a salary, and they pay your salary even if you don't invent anything. So, why give you more if one of the things happens to earn a patent?

What advice would you give someone who is thinking of pursuing chemistry?

You can do a whole lot of other things besides working in a lab if you have a science degree—it's going to help you in no matter what kind of career you choose. The scientific approach to solving problems is helpful in almost any area of your life. If you do choose to do straight chemistry, they need chemists not only in the research lab and in the control laboratory, but they need chemists in manufacturing and chemists in the legal departments. People don't understand how important the field is. If you get an opportunity like I did to jump into a field you like, grab hold of it and take it. And if you work in a lab and decide that you don't like it, get out and do something else. The world is your oyster nowadays—there are so many kinds of jobs that you can do. I don't see how kids ever make up their minds.

Christen Brownlee is a freelance science writer living in Washington, DC. Her last article, "Four Cool Chemistry Jobs", appeared in the December 2003 issue of *ChemMatters*.

ChemMatters

October 2004 Teacher's Guide

"Lab on a Stick"

Puzzle: Triple Cross

This puzzle's structure comes from famed puzzler Henry Hook. It has three parts. 1. Answer the across and down clues as best you can into the criss-cross grid. 2. Transfer letters in that grid to the QUOTE'S numbered spot(s); it may appear in there more than once! 3. As you begin to get the sense of the quote, you can work backwards to get clues missed first time around. We've filled in 1 across and 1 down to get you started.

You'll note every clue refers to a health/biochemical term, and the quote deals with a topic discussed in this issue of *ChemMatters*. It comes from a June 2004 *Consumers Reports* article on diet issues.

THE CLUES

ACROSS

1 Toxin associated with the mad hatter

13 Suffix denoting a sugar

16 Suffix denoting an aldehyde

26 Cocaine and serotine, for examples

39 Number of H atoms in a ribose molecule

48 C_2H_5OH and CH_3OCH_3, for example

59 Symbol of chemical in clue 1A

DOWN

1 Dura ____, a membrane protecting the brain

5 $(NH_2)_2C{=}O$, an important biochemical

10 Featured in the South Beach diet (hyphenated)

17 Environmental hazard released by discarded automobile batteries

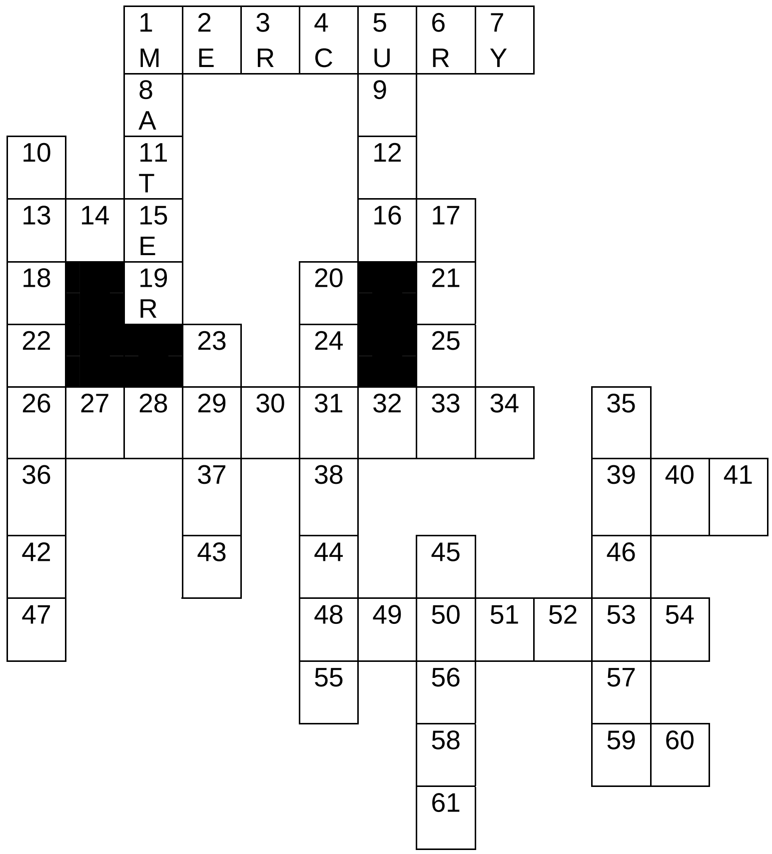
20 Chain of amino acids

23 Glyceryl esters; food group type

35 Long polymer of glucose units; a food group type

45 Any chemical that's hazardous to health

THE GRID



THE QUOTE

_ _ _ _   _ _   _ _ _   _ _ _ _ _   _ _ _ _   _ _ _   _ _ _ _ _ _ _ _   _ _ _ _   _ _ _ _ _ _ _

30 13 49 45   58 41   39 59 2   1 12 33 48 8   59 7 20 15   18 16 47   38 59 21 23 46 4 37   11 59 25 37   26 38 28 32 61 54

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33 58 40 45 44 3 43   18 52 9 2   29 57 39 5 46 17 27   7 10 31 35 48 55 60   18 12 32 60 59 38   34 58 51 20 30 7

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42 7   37 8 28 48 41 60   32 55   23 15 18 21 24   22 16 17 50 6 58 40 14   11 59 25 61 45 59 44 7   52 56 20 2 55 33 12 33

Puzzle Answers

THE QUOTE:

Lost in the media hype was the fact that Atkins dieters were actually losing weight simply by taking in fewer calories than they expended.

Consumers Reports, June 2004, p 14 in an article on low-carb diets and diet foods.

		1 M	2 E	3 R	4 C	5 U	6 R	7 Y				
		8 A				9 R						
10 L		11 T				12 E						
13 O	14 S	15 E				16 A	17 L					
18 W		19 R			20 P		21 E					
22 C			23 F		24 R		25 A					
26 A	27 L	28 K	29 A	30 L	31 O	32 I	33 D	34 S		35 S		
36 R			37 T		38 T					39 T	40 E	41 N
42 B			43 S		44 E		45 T			46 A		
47 S					48 I	49 S	50 O	51 M	52 E	53 R	54 S	
					55 N		56 X			57 C		
							58 I			59 H	60 G	
							61 N					

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Student Questions

Carb Crazy

1. What three elements are in a carbohydrate?
2. How is glucose used in the body?
3. What polysaccharide is a storage form of glucose?
4. What is the relationship between insulin and blood sugar?
5. By what basic principle do all diets work?
6. How is ketoacidosis different than ketosis?
7. Why would an athlete want to avoid a low carb diet?

Lab on a Stick

1. Why is sugar in urine a sign of a health problem?
2. What were two early tests for sugar in urine?
3. What is colorimetric test?
4. What additional test was developed to weed out false positive results for glucose?
5. How does the Multistix-10SG test for glucose?
6. Name any three medical conditions that the Multistix helps to identify?

Cleopatra’s Perfume Factory and Spa

1. How did Cleopatra acquire a spa and perfume factory?
2. What did chemists find when they analyzed a jar of Dead Sea mud treatment?
3. Where does the saying “Flies in the ointment” come from?
4. How were perfumes made in Cleopatra’s time?
5. What metal is present in Cleopatra’s green eye makeup?
6. What unexpected discovery did chemists make when they tested Cleopatra’s “signature” black eye makeup?

When Good Science Goes Bad!

1. Why was Patricia Stallings arrested?
2. What two substances found in Ryan Stallings blood led to the conclusion that he was poisoned?
3. Ryan was later thought to suffer from MMA. Why was this alternate explanation initially considered insufficient to overturn the conviction?
4. How and where do the separations of compounds occur in a gas chromatograph?
5. What happened when skeptical scientists doped blood samples with propionic acid and sent them for commercial GC-MS testing?
6. What treatment for ethylene glycol poisoning might have cause calcium oxalate crystals to form in Ryan’s brain?

Answers to Student Questions

Carb Crazy

1. What is a carbohydrate? Carbohydrates are composed of three elements: carbon, hydrogen, and oxygen.

2. How is glucose used in the body? Glucose is the body's primary fuel source. It is broken down during cellular respiration to release energy. Carbon dioxide is released as a waste product.

3. What polysaccharide is a storage form of glucose? Glycogen.

4. What is the relationship between insulin and blood sugar? Insulin can be thought as the gatekeeper for blood sugar entering cells. When insulin is released by the pancreas, blood sugar levels drop.

5. By what basic principle do all diets work? You must burn more calories than you consume.

6. How is ketoacidosis different than ketosis? During ketosis, fat is not completely broken down and your body produces and excretes ketone bodies. Ketoacidosis is an extreme form of ketosis where acid ketone bodies build up faster than they can be excreted. The result is a dangerous drop in blood pH and, if left untreated, coma and death.

7. Why would an athlete want to avoid a low carb diet? Athletes rely on glucose and glycogen reserves for quick energy. Most low-carb diets have an induction phase that consumes available glycogen reserves.

Lab on a Stick

1. Why is sugar in urine a sign of a health problem? Sugar in urine is a sign of high blood sugar levels and diabetes.

2. What were two early tests for sugar in urine? One test was to pour urine on the ground to see whether it would attract flies. A second test was to heat urine, cupric sulfate ($CuSO_4$), and a complexing agent. Presence of the reducing sugar, glucose, was confirmed by reduction of Cu(II) to Cu(I). This caused the mixture to change form blue to green, brown, and red. Not mentioned in the article was that early healers went as far as to taste urine to see if it was sweet.

3. What is colorimetric test? A colorimetric test relies on a visible color change to track the presence of a chemical.

4. What additional test was developed to weed out false positive results for glucose? The chemists at the Miles-Ames laboratory developed a urinalysis test for ketone bodies, a byproduct in diabetics urine caused by metabolizing fat instead of glucose.

5. How does the Multistix-10SG test for glucose? It uses glucose oxidase, peroxidase, and benzidine impregnated on a paper strip. The enzyme glucose oxidase catalyzes the breakdown of glucose into peroxide. Peroxidase catalyzes oxidation of benzidine with peroxide. Benzidine is a chromogen that changes color when oxidized.

6. Name any three medical conditions that the Multistix helps to identify? Any three of the following: Urinary tract infections, diabetes, kidney diseases, dehydration, infections, acid-base balance off, and liver damage.

Content Reading Materials

National Science Education Content Standard Addressed As a result of activities in grades 9-12, all students should develop understanding	**Cleopatra**	**Lab on a Stick**	**Carb Crazy**	**Antifreeze**	**QFTC***
Science as Inquiry Standard A: of abilities necessary to do scientific inquiry					✔
Science as Inquiry Standard A: about scientific inquiry.	✔	✔	✔	✔	✔
Physical Science Standard B: of the structure and properties of matter.	✔	✔	✔	✔	✔
Physical Science Standard B: of chemical reactions.	✔	✔	✔	✔	
Life Science Standard C: of the cell.			✔		
Life Science Standard C: of matter, energy, and organization in living systems.		✔	✔		
Science and Technology Standard E: about science and technology.	✔	✔	✔	✔	✔

Science in Personal and Social Perspectives Standard F: of personal and community health.	✔	✔	✔	✔	✔
Science in Personal and Social Perspectives Standard F: of science and technology in local, national, and global challenges.	✔	✔		✔	
History and Nature of Science Standard G: of science as a human endeavor.	✔	✔	✔	✔	
History and Nature of Science Standard G: of the nature of scientific knowledge.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of historical perspectives.	✔	✔			

*QFTC-Question From the Classroom

Reading Strategies

These content frames and organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding.

Lab on a Stick

History of Urinalysis

Date	**Chemicals and methods used**
Ancient times	
Early 1900s	
1930s	
1953	
Today	

Q & A with Helen Free

What H. Free liked about being a chemist	**What H. Free didn't like about being a chemist**
1.	1.
2.	2.
3.	3.

Anticipation Guides

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss their responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

Directions for all Anticipation Guides: In the first column, write "A" or "D" indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Lab on a Stick

Me	Text	Statement
		1. Type I and Type II diabetes have similar causes.
		2. Diabetes was known in ancient times.
		3. Diabetics have too much glucose in their urine.
		4. The 10-test strip developed by the Frees tests for the health of kidneys, liver, and blood sugar.
		5. Helen Free always wanted to be a chemist.
		6. Helen Free married her husband, then went to work for him.
		7. Helen Free earned millions from her 7 patents.

		8. Some chemists are needed in legal departments of chemical companies.

When Good Science Goes Bad!

Me	Text	Statement
		1. MMA (an inherited disease) and ethylene glycol (antifreeze) poisoning have similar symptoms.
		2. The metabolic products of MMA are similar to ethylene glycol.
		3. Quantitative analysis is superior to qualitative analysis.
		4. A gas chromatograph measures retention times of different compounds on an adsorbent material.
		5. Data from a mass spectrograph is compared to a database library to identify compounds.
		6. Colorimetric analysis is qualitative.
		7. Ryan's death was hastened by the treatment for ethylene glycol poisoning.
		8. Calcium oxalate dissolves in water.

Lab on a Stick

Background Information

ChemMatters has run several articles focusing on the use of urinalysis as a means for diagnosing a variety of diseases and conditions.

In April 1995, “Seeds of Doubt” by Bruce Goldfarb told the story of a nurse who tested positive for heroin in a urine sample as a result of eating a poppy seed bagel the evening before her drug screening test.

Following the Sydney Olympic Games, Australian writer Robert Morton contributed “Drug Detection at the Olympics—A Team Effort” (December, 2000). The article described how the use of various banned substances by athletes could be detected by analyzing urine samples collected prior to an event. Ways that unscrupulous competitors devise to hide these substances continues to challenge chemists hired to monitor the games.

In the October 2002, Doris Kimbrough authored the highly rated “Urine: Your Own Chemistry”, to describe how urine reflects the chemistry of the body. This article, explaining how the kidney’s perform their excretory functions, would make an effective companion to the current article. (Suggestion: Order the 20-year CD Rom of ChemMatters articles online at www.chemistry.org/education/chemmatters.html. Here you’ll find all of the articles from 1983-2003 with all available Teacher’s Guides in a printable, searchable format.)

Kidneys and Urine

A normal 24 hour urine output contains about 60 grams of solid material. About half of this is organic, consisting of substances like urea, uric acid, and creatinine. The inorganic portion will contain substances like sodium chloride, phosphates, sulfates, and ammonia. Normal urine should not contain any glucose or amino acids.

The amount of uric acid in a healthy person’s urine tends to vary over a relatively wide range from day to day. Normal serum levels of uric acid range from about 2.0-7.5 mg/dL for males and 2.0-6.5 mg/dL for females. Normal urine contains between 250-750 mg over a twenty-four hour period. Medical experts disagree about the exact range of uric acid to be considered normal. Uric acid is formed as the end product of purine metabolism. Purines are obtained from foods. Some foods high in purines include liver, kidneys, sweetbreads, sardines, anchovies, lentils, mushrooms, spinach and asparagus. Additional purines are produced from the breakdown of bodily proteins. The kidneys excrete about two-thirds of the uric acid the body produces. The remainder is eliminated in the stool.

Recently, high levels of uric acid in a person’s blood has been linked to an increased risk of dying from heart disease, especially in women and African Americans. In one study, 6,000 people aged 25-74 were followed for a period of sixteen years. They were divided into four groups— serum uric acid levels below 5.4, between 5.4-6.1, between 6.1-7.0, and above 7.0 respectively. Women at the highest level were about three times more likely to die from heart disease than women at the lowest level. The risk was 77% higher for similar groups of men. For all groups, the risk only showed itself for people aged 45 or older.

Urea holds a special place in the history of chemistry. First discovered in human urine in 1773, it is most notable because of Friedrich Wohler’s laboratory synthesis of the compound in 1828. What made this relatively simple synthesis so noteworthy was that prior to that time “organic” chemicals were considered to be molecules that could only be synthesized by living organisms. It was widely believed that molecules synthesized by a living organism could not be synthesized from their atoms in a laboratory because their synthesis required a "vital force" that only living things possessed. When Wohler synthesized urea while trying to synthesize ammonium cyanate and then demonstrated that the compound produced could not be distinguished from urea obtained from organic sources, it dealt a great blow to the concept of "vital force". Even today, a version of the "vital force" idea persists in the popular notion that vitamins obtained from "natural" sources are superior to vitamins synthesized in the laboratory.

Connections to Chemistry Concepts

Enzymes are biological *catalysts*. There is no all-encompassing definition of a catalyst, but an adequate definition is the following: A catalyst is a substance that speeds up the rate of a chemical reaction without being permanently consumed in the reaction.

Catalysts work by lowering the energy needed to get the two reacting molecules to react with each other. This energy is often referred to as the *activation energy* for the reaction, and the lower the activation energy, the greater the percentage of colliding molecules that are capable of reacting upon collision.

Some catalysts are never actually consumed. For example, a "surface" catalyst can function by simply holding a reacting molecule on its surface in a position where it is more likely to react with another molecule in its environment. Other catalysts are temporarily "consumed," in an early step in the reaction mechanism, but then regenerated in a later step.

Most biological catalysts are enzymes. A few are *ribozymes* with the catalytic activity occurring in the RNA part of the molecule rather than in the protein part.

For a more thorough discussion of catalysts in general and enzymes in particular, go to: http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/E/Enzymes.html

Possible Student Misconceptions

Both this article and the article on low-carb diets focus on the growing incidence of diabetes in our society. Students may have several misconceptions about the disease, e.g. That it is always hereditary, that it is caused by eating too much sugar, that it is easily "cured" by taking insulin, that all types of diabetes are the same, and many others. Excellent information is available from the American Diabetes Association at http://www.diabetes.org/about-diabetes.jsp. You might want to initiate a discussion by devising a simple True-False quiz to check how much your students know about the disease.

Demonstrations and Lessons

1. The publication "Celebrating Chemistry—Health and Wellness" posted by the ACS National Chemistry Week office for upper elementary and middle school students, contains an interesting activity in which multiple-test urinalysis strips are used to test a concocted "urine sample" for the presence of glucose and protein. The sample is actually pediatric electrolyte solution mixed with a small amount of powdered milk. While the procedure is fairly simple, it serves as an interesting demonstration of the test strip. Other additions to the "urine sample" might demonstrate other tests on the strip. Students could be challenged to design and, with your approval, perform related experiments to extend the use of the test strips beyond their use in urinalysis.

2. Testing for simple sugar in solution is accomplished by using a test reagent called Benedict Solution. The following instructions for making the reagent (also easily obtained from any chemical supply source) is as follows:

> A solution of 17.3 g of sodium citrate and 10.0 g of anhydrous sodium carbonate in 80.0 mL of water is heated until the salts are dissolved. Additional water is added to bring the volume up to 85.0 mL. A solution of 1.73 g of hydrated copper sulfate in 10.0 mL of water is poured slowly with stirring into the solution of the citrate and the carbonate. Add water to make a final volume of 100 mL.

The article describes how the presence of a strong reducing agent like glucose reacts upon heating with the blue cupric ions, readily changing them to Copper I which precipitates as an orange copper (I) oxide solid.

3. It might be of interest to invite a medical technician to talk to the class about current advances in screening and diagnostic testing.

Connections to the Chemistry Curriculum

The article connects to curriculum topics on solutions, oxidation and reduction, enzymes, catalysts, acids and bases, and several others. It also describes the importance of chemical testing in the diagnoses of disease and in the forensic urinalysis employed in screening for drug use.

Suggestions for Student Projects

Students might be challenged to devise their own test papers by using strips of filter paper and various testing reagents.

They might be challenged to invent other uses for the commercial test strips described in the article. Before doing so, they would need to read the information enclosed with the commercial strips as well as other information related to the tests.

Anticipating Student Questions

See the section on Possible Misconceptions for questions your students might have about diabetes.

Websites for Additional Information and Ideas

The following website offers a detailed account of the drug-screening urinalysis procedure used by the U.S. Department of Defense for recruits.
http://usmilitary.about.com/library/milinfo/bldrugtests.htm