# Enzymes may turn paper, grass into fuel

Imagine generating enough fuel from grass clippings, old newspapers, corn syrup, and cheese whey to run a car, light up a house, or heat a city. That flight of fancy remains science fiction, but investigators may have taken a small step toward realizing it with their recent development of an enzymatic method of transforming such renewable resources into hydrogen gas.

The prospect of using hydrogen as an environmentally friendly, or clean, fuel has long tantalized energy researchers. Unlike fossil fuels, whose combustion creates many pollutants, hydrogen generates little besides water when it burns. Moreover, in devices called fuel cells, hydrogen reacts efficiently with oxygen to produce electricity.

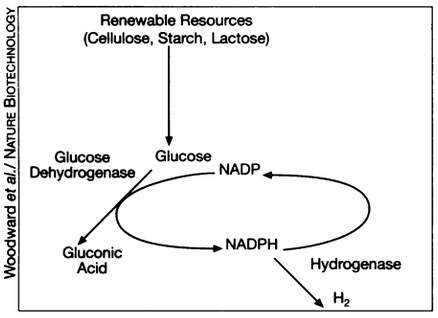
Hydrogen power has not yet been embraced by the world, in part because of an ironic scarcity of the ubiquitous element: Hydrogen is almost always bound up in chemical compounds. Current methods of hydrogen production include liberating it from water with the use of electricity, a technique called electrolysis, or breaking methane and other fossil fuels into their essential components, which include hydrogen.

Yet electrolysis is not cost-effective. Moreover, using nonrenewable fossil fuels to make hydrogen is not a favored long-term option, partly because that strategy generates waste gases such as carbon dioxide and carbon monoxide.

Enzymes stolen from bacteria may now offer another hydrogen production option, contend Jonathan Woodward of Oak Ridge (Tenn.) National Laboratory and his colleagues. In the July NATURE BIOTECHNOLOGY, they provide the first demonstration that a simple two-enzyme system can generate hydrogen gas from glucose.

"It's a long way from anything commercially viable, but I think it's a nice demonstration that such things are possible," comments Richard Cammack, who studies hydrogen production methods at King's College in London.

The new process first combines glucose with a bacterial enzyme called glucose dehydrogenase. In the presence of a compound known as NADP, this enzyme transforms a glucose molecule into gluconic acid and attaches a freed hydrogen atom to NADP, forming NADPH. Another enzyme, a hydrogenase isolated from bacteria found in a deep-sea hydrothermal vent, then releases the hydrogen from NADPH, generating hydrogen gas and enabling NADP to repeat the cycle.



Woodward *et al.*/ NATURE BIOTECHNOLOGY

*Using enzymes to convert renewable resources to hydrogen.*

Glucose would come from renewable resources such as cellulose, lactose, and starch, say the researchers. Wood pulp, grass clippings, and newspapers are excellent sources of cellulose that simply go to waste, Woodward points out. In Wisconsin, whey created in the process of making cheese offers a significant source of lactose, he adds.

Woodward's group has calculated that the cellulose in the waste newspaper generated each year in the United States could theoretically provide enough hydrogen to meet the energy demands of 37 cities the size of Oak Ridge, which has a population of around 27,000.

"We need to optimize conditions for hydrogen production, something I don't think we've achieved yet. Right now, the majority of material generated is not hydrogen, it's gluconic acid," says Woodward. While that product may also be mined for additional hydrogen atoms, gluconic acid itself is a valuable chemical compound currently used by a number of industries. —*J. Travis*

# Sleuths probe mystery of parasitic infection

Any mystery buff knows that a crime suspect must have motive, method, and opportunity. A medical sleuth trying to solve an epidemic also asks three questions: Who were the victims? Did their paths cross? Does the timing of the encounter suggest exposure to a microbe?

These are the questions that now perplex medical detectives caught up in The Case of the Apparently Infectious Berries—a remarkably widespread outbreak of intestinal infection that in 2 months has afflicted about 1,000 people in 12 states and Toronto. The culprit, *Cyclospora cayetanensis,* is a single-celled parasite that thrives in the intestine, causing cramps, diarrhea, and vomiting.

No one has died of the ailment, which can be cured with antibiotics. Just 10 people have been hospitalized. But the breadth of the epidemic has health officials scrambling to understand how *Cyclospora* has insinuated itself into the nation's food supply. Although the disease initially appeared in people who had eaten strawberries and raspberries, the link with fruit remains tenuous.

"We've only had three previous [*Cyclospora*] outbreaks in the United States—ever. This is not a disease that we've had a lot of opportunity to study," says Sue Binder of the Centers for Disease Control and Prevention (CDC) in Atlanta. The current outbreak is the largest on record.

First recognized as a cause of disease in 1977, *Cyclospora* is one of a number of infectious agents, such as HIV and Ebola virus, that have emerged over the past 2 decades. It was identified in the United States in 1990 at a Chicago hospital, where contaminated drinking water infected 21 people.

No one knows where in nature the parasite normally resides or how fruit might have become contaminated. Its life cycle is largely unknown, said Mark Eberhard, also of CDC.

The field investigation is being carried out mainly by state and local health officials in states with reported cases. These case reports answer the first question—Who is affected?—but do not reveal where or when people contracted the parasite.


CDC and published reports

*States hardest hit by* Cyclospora.

To answer those questions, researchers have undertaken three types of studies. First, they study disease clusters. Often, groups of people contract the infection at social events, Binder says. "You look at the foods served, how they were prepared, and interview people to see if there was some food that sick people ate and well people didn't."

The second approach is a case-control study, which makes possible investigation of isolated cases rather than clusters. Epidemiologists interview sick people and unaffected neighbors, trying to pin down some factor common to those who contracted the disease.

Finally, the Food and Drug Administration is carrying out a trace-back study to identify where infectious foods came from. Their work is complicated by *Cyclospora's* week-long incubation period, during which memories fade and food may be discarded, so it can't be tested.

In Houston, afflicted people ate strawberries. In Charleston, S.C., they ate strawberries and raspberries. The CDC reported on June 28 that fresh fruit may carry *Cyclospora*, and urged people to wash all produce before eating it. Despite an intensive search, however, no infectious produce has been found.

—*S. Sternberg*