Michigan**Science**

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ON THE COVER
Fluorescent lights now come in a variety of shapes and sizes for residential use.

By The Numbers

Beyond propaganda and rhetoric, numbers tell the real story

FEDERAL RESEARCH AND DEVELOPMENT GRANTS to universities and colleges for science and engineering totaled $29.2 billion in fiscal year 2005 — an increase of 5.6 percent from 2004, according to the latest survey by the National Science Foundation. The University of Michigan, with $809 million in grants, ranked second among the 640 institutions surveyed, behind Johns Hopkins University, which collected $1.4 billion. The 20 institutions collecting the largest grants accounted for 30 percent of federal university and college science and engineering R&D spending. The single largest share of funding went to life science research ($17.7 billion), followed by engineering ($4.1 billion); physical sciences ($2.67 billion); environmental sciences ($1.7 billion); computer sciences ($1 billion); social sciences ($691 million); psychology ($611 million); and math ($346 million). More numbers and analysis are available at http://www.nsf.gov/statistics/nsf07318/tables/tab71.xls; and http://www.nsf.gov/statistics/infbrief/nsf07311/.

THE DISCOVERY OF MASS GRAVES in Poland and Germany in 2005 prompted creation of a DNA database of Holocaust survivors and victims' relatives in hopes of identifying the remains. The database also is being used to unite an estimated 10,000 orphans with the 300,000 survivors worldwide. Of the 6 million Jews killed during the Holocaust, 2 million were cremated. The remaining 4 million were buried in mass graves throughout Europe, making genetic testing possible. DNA matching techniques developed after Sept. 11 and Hurricane Katrina are aiding in the identification of remains, more of which are being discovered in the course of development projects across Europe.

Time is of the essence, however; the average age of survivors is in the mid-80s. More information is available at http://www.dnashoah.info/.

BETWEEN 35 AND 50 NEW PLANTS would have to be built to maintain nuclear power's 20-percent share of the energy market, according to a July 2, 2007 report by the Associated Press. Currently, there are 104 commercial nuclear reactors nationwide. The U.S. Department of Energy estimates that demand for electricity will grow 45 percent by 2030. Licenses are currently being sought for 33 new reactors, according to the Nuclear Regulatory Commission. Each plant takes at least seven years to build and bring online. The AP article is available at http://www.enn.com/todays-news/13061.

THE COST OF GREENHOUSE GAS regulations would fall disproportionately on the poor, according to a recent report from the Congressional Budget Office. Higher prices for fuel and electricity resulting from a 15-percent cut in carbon dioxide emissions would cost the poorest Americans (those in the lowest one-fifth of the income distribution) about 3.3 percent of their average income. By comparison, such regulations would cost a household in the top income range about 1.7 percent of its average income. The CBO report is available at http://www.cbo.gov/ftpdocs/80xx/doc8027/04-25-Cap_Trade.pdf.

*Just the Facts

Media outlets nationwide have been commemorating the centennial birthday of Rachel Carson, whose 1962 book "Silent Spring" is considered by many to be the inspiration for the modern environmental movement. A May 25 commentary in the Detroit Free Press, for example, credited Carson with begetting the Clean Water Act, the Endangered Species Act and the Great Lakes Water Quality Agreement between the United States and Canada.

In fact, a great deal of Carson's conclusions about human health and the environment were wrong, more the product of her imagination than proper scientific research. As noted by John Tierney in The New York Times on June 5, Carson was wholly incorrect in asserting that there exists no safe dose of synthetic pesticides. Indeed, Bruce Ames, professor of biochemistry and molecular biology at the University of California, Berkeley, has determined that most potential carcinogens are ingested in such small quantities that they have little to no impact on human health.

Carson's claims that the pesticide DDT caused cancer in humans ultimately prompted the U.S. Environmental Protection Agency to ban the pesticide in 1972. However, the DDT ban was responsible for the needless deaths of tens of millions of people. DDT had been largely responsible for reducing malaria deaths worldwide, from 1,740 per million in 1930 to 480 per million in 1950 — a 70 percent decrease.

In actuality, the increase in cancer deaths cited by Carson was due to fewer people dying at young ages from other diseases.

Holding her controversial book "Silent Spring," Rachel Carson stands in her library in Silver Springs, Md., on March 14, 1963. She said she wanted to bring to public attention her charges that pesticides are destroying wildlife and endangering the environment. *(AP Photo)*

DDT does pose risks to birds such as eagles and other raptors. But as Tierney points out, Carson "wildly imagined" a "mass biocide" and the extinction of the robin, which "was an especially odd claim given the large numbers of robins recorded in Audubon bird counts before her book." Nor was Carson the first to investigate the impact of pesticides on the environment, as some devotees claim. The National Academy of Sciences conducted research on pesticides and the environment long before Carson put pen to paper, according to Tierney.

There is no doubt that the environment has improved substantially since the early 1960s, when "Silent Spring" was published. But the recent accolades heaped upon Carson ignore her most significant contribution to modern environmentalism: While she imbedded in the public consciousness a concern for the affects of chemicals on the environment, she also grossly overstated the risks of pesticides. Unfortunately, her simplistic environmental theories fomented unfounded fears about synthetic chemicals that persist today.

Detroit Free Press commentary is available at http://www.freep.com/apps/pbcs.dll/article?AID=/20070525/OPINION02/705250331/1070/OPINION02; Tierney's commentary is available at http://select.nytimes.com/search/restricted/article?res=F00D15FA3A540C768CDDAF0894DF404482 (subscription required); for more information on Rachel Carson, see Make Earth Day About Science, Not Unfounded Fears at http://www.mackinac.org/article.aspx?ID=8379.

Field Trips

Area science museums host special programs of interest to budding scientists and their families

DinosauRevolution

Would-be paleontologists and their parents can experience the Triassic, Jurassic and Cretaceous periods by traversing a maze filled with hands-on activities covering 150 million years of dinosaur history. The exhibit also features a fossil dig.

May 25 – Sept. 3, 2007, Cranbrook Institute of Science, 39221 Woodward Ave., Bloomfield Hills, 248-645-3200. Museum is open Saturday through Thursday, 10 a.m.-5 p.m.; Friday, 10 a.m.-10 p.m. Cost: $8 adults; $6 seniors and kids; free for children aged 2 and under.

For more information, go to http://science.cranbrook.edu/common/news_detail.asp?L1=7&L2=0&newsid=257882

Hatching the Past

This interactive exhibit features real fossils, including the 75 million-year-old fossilized egg laid by a titanosaur in Argentina; a nest of eggs laid by a duck-billed, plant-eating dinosaur; and the nearly 18-inch eggs laid by the ostrich-like, carnivorous oviraptor — the longest dinosaur eggs yet discovered. A video display introduces guests to "Baby Louie," the nearly complete skeleton of a dinosaur embryo (shown top right) discovered in China by Charlie Magovern in 1993.

Sept. 2007 – May 2008, Impression 5 Museum, 200 Museum Drive, Lansing, 517-485-8116. Museum is open Monday through Saturday, 10 a.m.-5 p.m.; Sunday, 1 p.m.-5 p.m.

For more information go to http://www.impression5.org.

~~Nine~~ Eight Planets and Counting

How many planets in our solar system? It was widely believed to be nine before Pluto lost its planetary designation last year. But the actual number of planets orbiting our sun may be 10, 12 or even more. The planetarium show **~~Nine~~ Eight Planets and Counting** offers a fascinating look at the latest discoveries about the solar system.

Opens Sept. 15, 2007, The New Detroit Science Center, 5020 John R St., Detroit, 313-577-8400. Center is open Monday through Friday, 9 a.m.-3 p.m.; Saturday 10:30 a.m.-6 p.m.; and Sunday, 12 p.m.-6 p.m.

For more information go to http://www.detroitsciencecenter.org/events/htm.

Courtesy NASA/JPL-Caltech

THE THIRD DEGREE

Test your reading of this issue of MichiganScience.

Students in grades six through 12 can compete for a $100 gift certificate from Edmund Scientifics®. The winner will be determined by a random drawing from entries with all the correct answers.

1. **By what percentage did DDT reduce malaria cases between 1930 and 1950?**
   A. 70 percent.
   B. 65 percent.
   C. 50 percent.
   D. 35 percent.

2. **Which university receives the largest amount of federal research grants for science and engineering?**
   A. University of Michigan.
   B. Cornell University.
   C. Johns Hopkins University.
   D. Michigan Technological University.

3. **What percentage of U.S. electricity is supplied by nuclear power?**
   A. 10 percent.
   B. 20 percent.
   C. 25 percent.
   D. 32 percent.

4. **What percentage of the energy generated by combustion is lost as heat in an internal combustion engine?**
   A. One-quarter.
   B. One-third.
   C. One-half.
   D. Two-thirds.

5. **What does the acronym CVT stand for?**
   A. Compressed V8 Timing.
   B. Continuously Variable Transmission.
   C. Computerized Valve Technology.
   D. Consistency Variant Tires.

6. **What is the name of the scientist who developed the Red Queen Hypothesis?**
   A. Charles Dodgson.
   B. Louis Leakey.
   C. Carroll Lewis.
   D. Leigh Van Valen.

7. **How many light sockets are in the average American household?**
   A. 25.
   B. 35.
   C. 45.
   D. 50.

8. **What percentage of domestic energy is used for lighting?**
   A. 5 percent.
   B. 10 percent.
   C. 12 percent.
   D. 22 percent.

9. **What percentage of energy used by an incandescent bulb is converted to light?**
   A. 75 percent.
   B. 50 percent.
   C. 10 percent.
   D. 5 percent.

10. **How much mercury is contained in an average fluorescent bulb?**
    A. 5 milligrams.
    B. 10 milligrams.
    C. 25 milligrams.
    D. 35 milligrams.

Mail answers to Bruce Edward Walker, The Mackinac Center for Public Policy, 140 West Main Street, Midland, Mich. 48640, or e-mail answers to Walker@mackinac.org. Please include your name, address, grade, school and the name of your science teacher.

HATCHING IDEAS ABOUT EVOLUTION

Resurrection of eggs from Michigan sediment enlivens research

BY W. CHARLES KERFOOT, PH.D.

In the 1990s, an international team of scientists discovered a method to hatch microscopic animals from eggs more than a century old. The eggs were extracted from the remains of zooplankton collected from lake sediment and hatched in an incubator. The zooplankton subsequently grew to maturity. This feat of perpetual reproduction, which has come to be known as "resurrection ecology," is revolutionizing the study of evolution. »

HATCHING IDEAS ABOUT EVOLUTION

Researchers at Michigan Technological University, in Houghton, are at the forefront of resurrection ecology. From the sediments of Lake Michigan and Portage Lake, in the Keweenaw Peninsula, eggs dating back nearly a century are being retrieved, hatched and compared with their contemporary cousins to track changes in the species.

The Bosmina resting egg pictured above was retrieved from Portage Lake in Michigan's Upper Peninsula.

The value of this research process is immeasurable. In the case of zooplankton, as many as 30 successive generations may live and die in a lake in a single year. If the eggs from each generation are viable for 100 years or more, a sediment sequence may contain 3,000 generations in total. In human terms, the hatching of a 100-year-old zooplankton egg is equivalent to resurrecting a human being from the dawn of Homo sapiens more than 120,000 years ago.

During the past several years, the Michigan Tech researchers have been hatching the eggs of a small crustacean, *Daphnia retrocurva*, to test the hypothesis that predators and their prey constantly evolve in response to changes in each — or perish in the process. Their work offers evidence that predators and prey do simultaneously co-evolve as partners in a dance through time. Additionally, there is evidence that individual species undergo rapid changes to increase their resistance to predators, disease and environmental hazards as well as their ability to compete with other species.

The scientists are using *D. retrocurva* because the eggs are relatively easy to identify visually. Portage Lake and Lake Constance in Germany are ideal sites for this research because both feature sediments that are simple to date using the radioactive isotopes lead 210 and caesium137. These two isotopes are preferable to carbon 14 for dating sediments because their radioactive half-lives (22 years and 30 years, respectively, compared to the 5,700-year half-life of carbon 14) produce more exact measurements. Lead 210 and caesium 137 can accurately determine the age of lake sediments within two years to three years, whereas carbon 14 can only date a sample within a range of 100 years.

In the case of *D. retrocurva* from Portage Lake, scientists wanted to know what changes, if any, have occurred in the past 80 years, a period when the lake experienced major upheavals due to mining, dredging and stagnation.[1]

It was discovered that *D. retrocurva* changed significantly during the 80-year period under study. In particular, there were changes in their helmets and spines in direct relation to fluctuations in predator populations — changes that would make *D. retrocurva* less appetizing. In other words, as the number of predators increased, the *D. retrocurva* changed in ways that would help to preserve its numbers against greater predation. Such micro-evolutionary adjustments had been observed in *D. retrocurva* fossils, but resurrection ecology brought the historical record alive.

The pioneers of resurrection ecology[2] assembled in Germany in the 1990s to explore ways to revive the zooplankton populations of eutrophic lakes. By demonstrating the viability of decades-old and century-old eggs, they established a new process to test many hypotheses that had been difficult, if not impossible, to examine because of time scales. By retrieving "resting" or "diapausal"[3] eggs for DNA analysis, enzyme characterization and other testing, scientists can now examine evolution over time and space; document the timing and frequency of local colonization and extinction events; and provide an accurate historical biological assessment of ecosystem perturbations.

The first research employing resurrection ecology involved *cladocerans* (small freshwater crustaceans) and sediment chemistry that were examined alongside changes that could be documented through conventional study of fossils.[4] The study of *D. retrocurva* eggs from sediment cores revealed that the species changed genetically over the span of just 80 years. In most instances, the evolutionary change was evident in the spines and helmets of the organisms to adapt to the environment and the threat of predators.

More recent experiments have involved microparasites, pathogens and epibionts.[5] Michigan Tech scientists have hatched eggs from all three categories, although their research has not yet extended to tracking evolutionary changes.

THE RED QUEEN HYPOTHESIS

"Well, in our country," said Alice, still panting a little, "you'd generally get to somewhere else — if you ran very fast for a long time as we've been doing."

"A slow sort of country!," said the Queen. "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that."

— Lewis Carroll in *Through the Looking-Glass and What Alice Found There*

1 Eutrophication of a lake occurs when an excess of nutrients such as nitrogen and phosphorous promotes inordinate growth of aquatic plants, resulting in the depletion of oxygen.

2 The author; N.G. Hairston, Jr. and C.E. Caceras of Cornell University; and L.J. Weider of the Max Planck Institute of Limnology.

3 A form of hibernation marked by reduced metabolism and activity.

4 Hairston et al. 1999b, 2001; Kerfoot et al. 1999; Kerfoot and Weider 2004; Jankowski and Straile 2003.

5 Organisms that attach to the exoskeleton of a host organism, but cause no direct harm.

A Daphnia retrocurva resting egg retrieved from Portage Lake.

Researcher Leigh Van Valen, at the University of Chicago, postulated in 1973 that organisms must continually evolve for a species to survive. He dubbed his theory "The Red Queen Hypothesis."

Van Valen was fascinated by changes in the shells of mollusks and their rates of extinction. When he plotted the species' extinction rates on a logarithmic scale, he obtained a straight line, which suggested a constant rate of extinction. He viewed the changes in the mollusks' shells as both evolutionary responses to changes in the environment (morphological) and the consequences of natural selection (genetic) based on competitive species and predatory interactions.

Van Valen believed that his hypothesis could not be proved because testing at that time could only be done using fossil records. But using only fossils, which are non-living remains, was very difficult because of the absence of samples from generations uninterrupted across time. When scientists have access to the ancestors of organisms that are still living, it is possible to study behavior and reproduction. In any event, because most fossils are scattered, they do not constitute a continuous time record.

To prove the theoretical co-evolution between host and pathogen, scientists required the genetic feedback provided by resurrection ecology, that is, live specimens from hundreds if not thousands of generations. Prior to the research at Lake Constance and Portage Lake, such study seemed unlikely, if not impossible.

Using resurrection ecology, scientists gathered evidence that predators change along with their prey, proving that the Red Queen Hypothesis holds true for the microorganisms from Portage Lake. Resurrection ecology also has enabled scientists to study evolution prompted by environmental changes. What has been witnessed is the essential ability of species to compete and survive through time. In other words, species must continually evolve in order to survive.

Because a great quantity of aquatic species in temperate lakes produce resting eggs, and these eggs subsequently have been buried in conformable sediments (chronologically layered sediments that form on top of each other), scientists are better able to track lineages of species through time. In terrestrial environments, trees and shrubs produce seeds, but the burial in soil is much more erratic and difficult to date. The viability of eggs from aquatic microorganisms, after more than a century, demonstrates nature's remarkable resiliency. Within the stores of reclaimed eggs are untold discoveries just waiting to be hatched. ■

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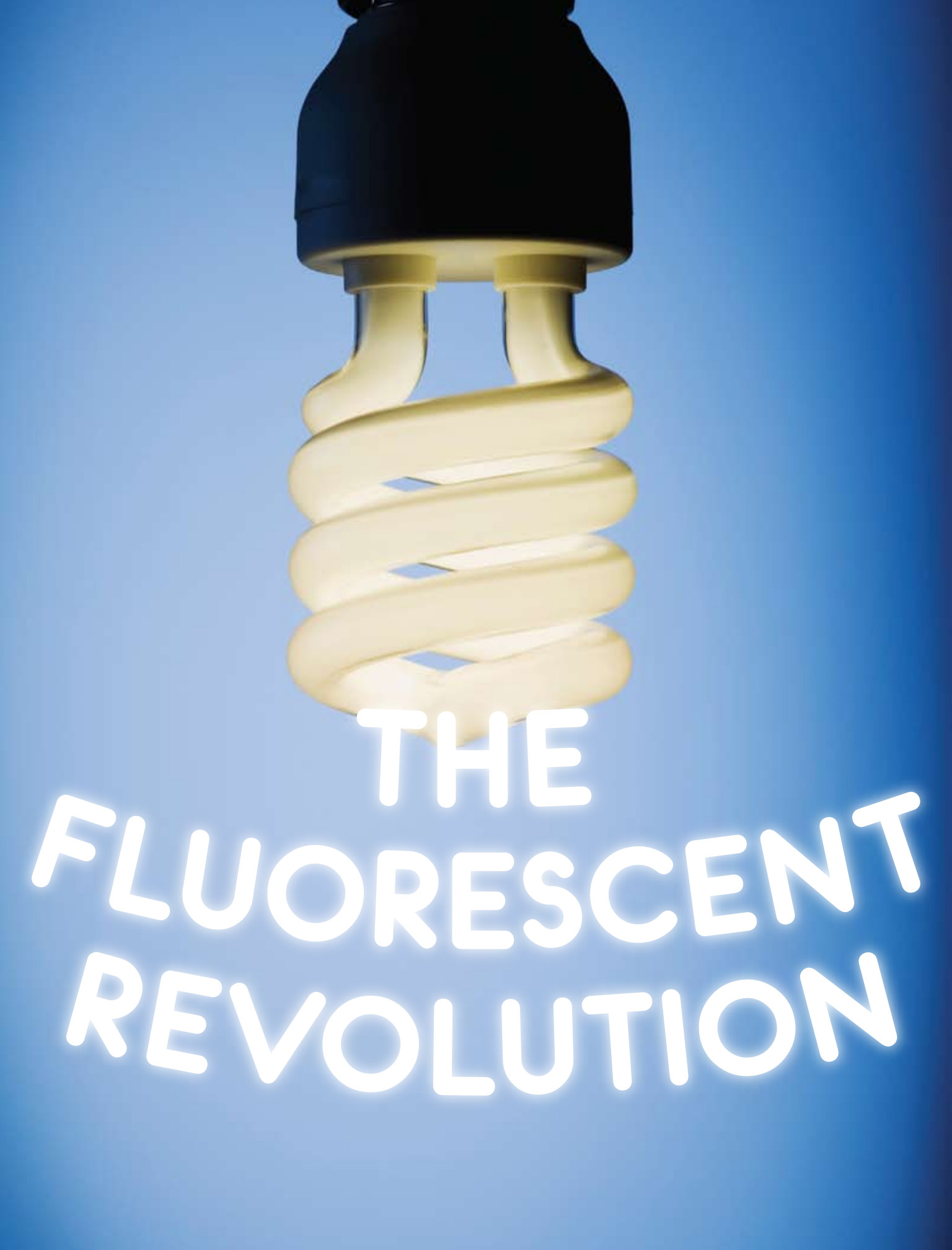

THE
FLUORESCENT
REVOLUTION

More energy-efficient lighting is challenging the reign of the incandescent bulb. But the alternatives involve trade-offs, too.

By Diane S. Katz

Thomas Edison's monumental gift to modernity, the incandescent light bulb, no longer will be sold in Australia, Canada, Cuba or Venezuela within five years. Similar phase-outs are pending in California, New Jersey and several other states as well as the European Union. Ban-the-bulb advocates contend that Edison's creation is inefficient and that fluorescent lights are far more environmentally friendly. While this is certainly true in some respects, it is not exclusively so. Moreover, lighting alternatives now under development may soon prove to be superior to both incandescent and fluorescent bulbs.[1]

New regulations on lighting carry enormous consequences for consumers. The average American home features 45 light bulb sockets, and lighting accounts for 9 percent of the electricity used in the average U.S. household. Americans spend $37 billion annually for lighting, which consumes 22 percent of all electricity generated domestically.[2]

The campaign to extinguish incandescent bulbs is fueled in large part by concerns over the environmental impact of electricity production — primarily emissions of carbon dioxide. Michigan Sen. John Gleason (D-Flint) introduced legislation on June 12 that would, if enacted, criminalize the sale of incandescent bulbs in the state beginning in 2012.[3]

Compared to some other lighting sources, the incandescent bulb is an energy hog; its light is a product of heat. The glass sphere of the bulb contains a tungsten filament. When electricity is introduced, the threadlike diameter of the filament creates resistance to the energy flow. The resulting buildup of energy creates heat, which makes the filament glow (incandesce). Consequently, only 10 percent of the energy used by the bulb actually produces light. The remaining 90 percent is released as heat. So, for every watt of input power, an incandescent bulb typically produces only 15 lumens (the measure of light output).[4]

A fluorescent light, by contrast, produces 50 to 100 lumens per watt, depending on the type of bulb. Thus, the fluorescent light is four-to-six times more energy efficient than the incandescent variety. As the chart to the right indicates, a fluorescent bulb uses much less electricity to produce the same amount of light as an incandescent bulb.

Wattage Equivalents

Incandescent Bulb	Fluorescent Bulb
60 Watt	13-15 Watt
75 Watt	20 Watt
100 Watt	26-29 Watt
150 Watts	38-42 Watt

Source: General Electric

A fluorescent bulb works by transforming ultraviolet light into visible light. A fluorescent bulb is filled with argon and mercury vapors, and the inside of the glass is coated with a phosphor. When electricity flows to the bulb, a reaction between electrons and the gas vapors produces ultraviolet photons. The photons are then absorbed by the phosphor coating inside the bulb, which produces the visible light. Because the fluorescent bulb loses relatively little energy as heat — some 60 percent less than an incandescent bulb — it requires less electricity to achieve the same amount of light.

There is a cost to achieve the relative efficiency of fluorescent bulbs — they require about four times more energy to produce than incandescent lights

1 Fluorescent lights are now available in a variety of shapes and sizes, not just tubes. Bulbs that fit lamps and other fixtures are referred to as "compact fluorescent lights" or CFLs.

2 U.S. Department of Energy, Energy Information Administration.

3 As proposed, the legislation calls for violators to face up to 90 days in jail and a $1,000 fine. SB 578 is available on the World Wide Web at http://michiganvotes.com/Legislation.aspx?ID=53726

4 One lumen is the equivalent of the light given off by one candle.

and thus are far more expensive.[5] A fluorescent bulb can cost between three times and 10 times more than a comparable incandescent bulb.[6] Still, over the lifetime of an average bulb, consumers can realize a net savings in energy costs of about $30 to $40 per bulb if used as recommended.

The economics of fluorescent bulbs versus the incandescent variety are not fixed, however. The heat of incandescent lights — more than 341 Btu per bulb per hour[7] — can help to warm a room. Therefore, if the cost of electricity is low relative to the cost of home heating fuel, there may be an economic case for changing to incandescent bulbs in colder seasons.

For advocates of new lighting regulation, bulb economics are a secondary benefit. The more important advantage of fluorescent bulbs, they say, is the presumed reduction in CO2 emissions from reduced energy consumption.

Less than 6 percent of American households currently use fluorescent lights. In the minds of many consumers, fluorescent light is harsh; the bulbs flicker and buzz incessantly. But advances in lighting technology have improved their performance.

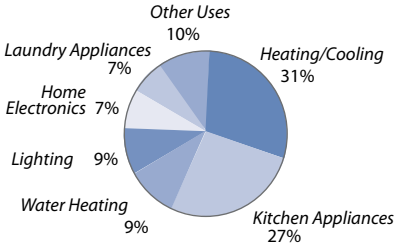
No longer do all fluorescent bulbs emit the cold, eerie blue light of their older cousins. The color differences among various types of bulbs are a function of temperature. Incandescent light appears warmer because it is hotter, while fluorescent lighting is cooler, and thus whiter. But fluorescent bulbs in "warmer" shades of white are now available thanks to an array of phosphor blends. The choice of light color does involve tradeoffs, however. Greater "warmth" in a fluorescent will diminish a bulb's efficiency and shorten its lifespan.

5 A compact fluorescent requires about 4 kWh of electricity to be made; an incandescent about 1 kWh.

6 U.S. Dept. of Energy, "A Consumers Guide to Energy Efficiency and Renewable Energy." Available on the World Wide Web at http://www.eere.energy.gov/consumer/your_home/lighting_daylighting/index.cfm/mytopic=12050.

7 A fluorescent bulb generates 92.18 Btu an hour.

Electricity Consumption by Use
U.S. Households (2001)



Source: Energy Information Agency, U.S. Department of Energy

Fluorescent bulbs were long relegated to the workplace largely because of their unfavorable "rendering" of color.[8] Under fluorescent lights, complexions can take on the dull, gray cast of a corpse. Fortunately, manufacturers have improved the rendering of fluorescent bulbs with the development of new phosphor blends.[9]

Rather than just the tubes of old, fluorescents are now available in a variety of shapes and sizes to fit lamps and ceiling fixtures. The tube design is a relic of the external "ballast" within a ceiling fixture that once was required for fluorescent bulbs to operate. The ballast regulates voltage; greater power is needed to turn on the light, but the current must be limited to sustain it. The development of an "integral ballast" contained within the bulb instead of in the fixture has allowed fluorescents to assume a variety of shapes.

Integral ballasts also have helped to eliminate the annoying buzz and flicker of fluorescent lights. Historically, these ballasts have been magnetic devices that operated at only 60 cycles per second, which produced a strobe effect. Newer electronic ballasts operate at 24,000 cycles per second, which eliminates the flicker. Moreover, there's little of the vibration that caused older bulbs to buzz.[10] Electronic ballasts are also smaller and lighter, which improves bulb efficiency.

Concerns have been raised about the use of mercury in fluorescent lights, which amounts to about 5 milligrams per bulb, on average.[11] In reality, consumers face a greater risk of getting cut by the glass of a broken bulb than being poisoned by the mercury within it. Manufacturers do recommend sealing a spent fluorescent bulb in a plastic bag before disposal, and the bulbs should not be incinerated. But only large commercial users of tubular fluorescent lamps are required to recycle them.

Fluorescents are not without their drawbacks. Most require a warm-up period of up to three minutes before reaching full brightness. They are not recommended for use with ceiling fans or garage door openers, the vibrations of which can cause the bulbs to fail. Most are not suitable for use with dimming switches. Moreover, fluorescent bulbs may cause electronic devices to malfunction temporarily if they "misread" the infrared light.[12]

The efficiency and lifespan of fluorescents are diminished if the bulbs are switched on and off throughout the day, as in bathrooms and bedrooms, for example. They are best utilized for lighting that is left on for several hours at a stretch. But the average household has only 2.5 lights that are on four hours or more per day — typically in the living room and kitchen.[13]

Notwithstanding the benefits of fluorescents, research is underway to improve the energy efficiency of incandescent lighting. General Electric, for example, is preparing to market a "high efficiency incandescent" (HEI™) lamp to match the energy efficiency of a fluorescent bulb at a lower price.

Also gaining considerable attention is

8 The accuracy of rendering is rated under the Color Rendering Index, which ranges from 0 to 100, with higher values closer to ideal.

9 http://www.lightingdesignlab.com/articles/fluor/hatefluor.htm

10 http://www.lightingdesignlab.com/articles/fluor/hatefluor.htm

11 In comparison, home thermometers used to contain about 500 milligrams of mercury; manual thermostats about 3,000 mg.

12 General Electric.

13 U.S. Dept. of Energy, Energy Information Agency.

*"I already told you. Incandescents use too much energy, and CFLs contain mercury. **That's** why we switched to torches."*

"LED" lighting, or light emitting diodes. Although widely used currently for decorative lighting, traffic lights, and in toys, appliances and keypads, researchers are developing LED technology for residential and commercial applications.

LEDs are composed of wafer-thin materials coated with a conducting element such as gallium or industrial sapphires. The wafers are typically encased in glass. When stimulated by electricity, the LED emits light — the color of which depends on the particular coating applied to the wafer.

LEDs have the advantage of being easily integrated into a variety of building materials, and they can deliver light across multiple planes.[14] Unlike fluorescents, they reach full brightness in microseconds. LEDs also last extremely long, with a lifespan estimated to be as much as 1 million hours. Fluorescent tubes typically are rated for 10,000 hours, and incandescent bulbs at 1,000 to 2,000 hours.

"(W)e ought to be focusing more effort on using electronics to meet our lighting challenges and less on using mercury and phosphor to make light," wrote Nicolas Mokhoff for Electronic Engineering Times.[15]

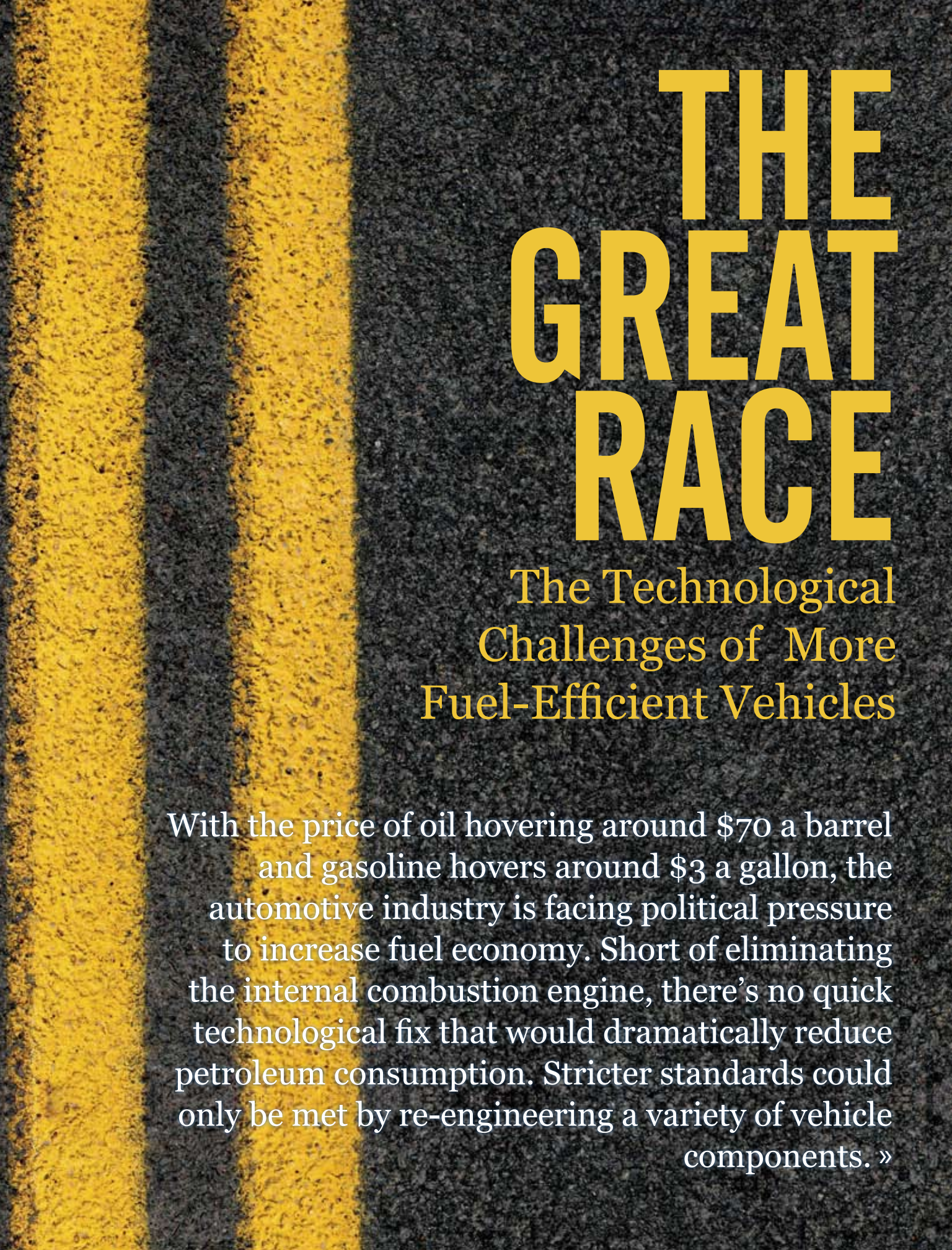
The chief impediment at present is cost. The typical LED is composed of at least several diodes. An equivalent of a 25-watt incandescent bulb runs about $50. But the average price of a single white diode has fallen from $8 to $1.50 in the past year. Mass production could further drive down the price.[16]

The nature of lighting has changed dramatically throughout human history. Man first used wood fire to break the darkness, before discovering the utility of plant and animal oils. Next came candles of tallow and beeswax, followed by phosphorus and various gas lamps. Thomas Edison's incandescent bulb lit the late-1800s, and the twentieth century brought fluorescents and LEDs. What the future holds remains to be seen, but there's every reason to believe that human ingenuity will brighten the future. ■

14 Knisley, Joe, "Led Report," Electrical Wholesaling, Feb. 20, 2007, pg. 26.

15 Mokhoff, Nicolas, "Let There Be Solid-State Light," Electronic Engineering Times, March 26, 2007, pg. 2.

16 Svensson, Peter, "LEDs Gain Favor for Low Energy Consumption," The Ledger, May 11, 2007.



THE GREAT RACE

The Technological Challenges of More Fuel-Efficient Vehicles

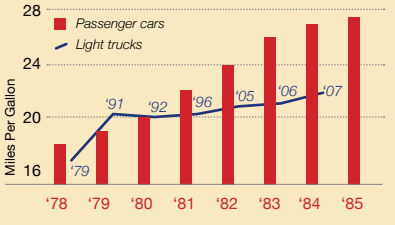
With the price of oil hovering around $70 a barrel and gasoline hovers around $3 a gallon, the automotive industry is facing political pressure to increase fuel economy. Short of eliminating the internal combustion engine, there's no quick technological fix that would dramatically reduce petroleum consumption. Stricter standards could only be met by re-engineering a variety of vehicle components. »

By Henry Payne and Bruce Edward Walker

Automakers are currently required to meet a fleet-wide average fuel economy[1] of 27.5 miles per gallon for passenger cars and 22.2 mpg for light trucks. The U.S. Senate energy bill passed in July 2007 calls for raising CAFE standards to 35 mpg by 2020 for cars and SUVs.

Corporate average fuel economy standards — dubbed CAFE — were first enacted by Congress in 1975, in the aftermath of the 1973 Arab oil embargo. At the behest of Congress, the National Highway Traffic and Safety Administration sets the standards; the U.S. Environmental Protection Agency calculates the average fuel economy for each manufacturer.[2]

Corporate Average Fuel Economy Levels 1978-2007



Source: National Highway Traffic and Safety Administration, http://www.nhtsa.dot.gov/cars/rules/cafe/overview.htm.

CAFE was intended originally to reduce U.S. demand for foreign oil. The goal has since expanded to include environmental protection, e.g., reductions in emissions of carbon dioxide.

The U.S. auto industry spends an estimated $21 billion each year on fuel efficiency and alternative fuel technologies, as well as vehicle design and safety.[3] In a letter to employees of Daimler Chrysler AG, executive Tom LaSorda estimated that it would cost $11.2 billion over five years to raise the company's fleet average to 36 mpg by 2022 and to 30 mpg for light trucks by 2025, as proposed by Michigan Sen. Carl Levin.[4] President George W. Bush has called for a 40 percent increase in CAFE, to 35 mpg within 10 years, while other legislation pending in Congress would set the standard at 52 mapg by 2030.

According to the National Research Council, the average fuel economy of new passenger cars nearly doubled between 1970 and 1982, and increased by 50 percent in new light trucks during the same period.[5] Additionally, the NRC reported that the entire U.S. light-vehicle fleet increased 66 percent by 1992.[6]

These improvements in fuel efficiency have been achieved, in part, by downsizing vehicles, the use of lighter auto body materials such as plastics, aluminum and fiberglass, and body construction, i.e. casting the vehicle body and underlying frame as a single component.

Simple physics dictates that it takes less fuel to operate a lighter vehicle. In 1975, the average U.S. passenger car weighed 4,380 pounds compared to 1,676 pounds for European cars and 1,805 pounds for Asian cars.[6] The "weight gap" had narrowed dramatically by 2000, when the average American vehicle was 75 pounds lighter than the average European car and just 245 pounds heavier than the average Asian car.[7]

Vehicle aerodynamics have also improved. The lower the wind resistance, the less fuel required to propel a vehicle. The majority of newer models are rounded rather than boxy, prompting more than one reviewer to liken them to jellybeans.

Reducing engine friction also improves fuel efficiency. Engineers thus have designed fewer moving parts and developed better lubricants. Additional fuel savings have come from a transition to front-wheel-drive power trains. According to the National Resource Council, only 1.3 percent of U.S. passenger cars were front-wheel drive in 1975, compared to 17 percent of Asian models and 46 percent of European models.[8] The majority of U.S. vehicles built today are front-wheel drive.

Advancements have also been made in fuel delivery systems. Direct fuel injection has improved upon the relative inefficiency of carburetors by delivering a more precise measure of gasoline to each cylinder. Less than 1 percent of U.S. passenger cars were fuel-injected in 1975, compared to 14 percent of Asian vehicles and 39 percent of European vehicles.[9] Today, fuel injection has replaced the carburetor in nearly all vehicles rolling off U.S. assembly lines.

Fuel efficiency still can be increased by further improvements in fuel-injection technology. Although most conventional American vehicles employ electronic fuel injection or multi-port injection systems, a direct injection system would burn less fuel and generate less heat by delivering the fuel directly to the cylinder rather than routing it through an intake valve. Direct injection technology is widely available in Europe, in both gasoline and diesel engines. But U.S. emissions standards have limited the introduction of direct-injection diesels here.[10]

Currently, only 12 percent to 20 percent of the gasoline burned in an internal combustion engine is used to propel the vehicle. Two-thirds of the energy created by combustion is lost as heat, which is why engine coolants are necessary. The remainder of the energy is lost to engine friction and the powering of air conditioning and a host of other features. Losses also occur during idling and deceleration because fuel continues to combust even as the vehicle coasts or is no longer in motion.

1 Corporate Average Fuel Economy (CAFE).

2 National Highway Traffic and Safety Administration, http://www.nhtsa.dot.gov/cars/rules/cafe/overview.htm

3 Wards Automotive Facts and Figures 2005, National Science Foundation. Information is accessible to nonsubscribers at http://www.weberchevrolet.com/sale/american.pdf.

4 Wall Street Journal, "Michigan's Levin Prepares Fuel-Economy Measure," by Mike Spector, June 14, 2007.

5 National Research Council, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, page 14. Available online at http://www.nap.edu/books/0309076013/html/.

6 National Research Council, page 15.

7 National Research Council, page 15.

8 National Research Council, page 15.

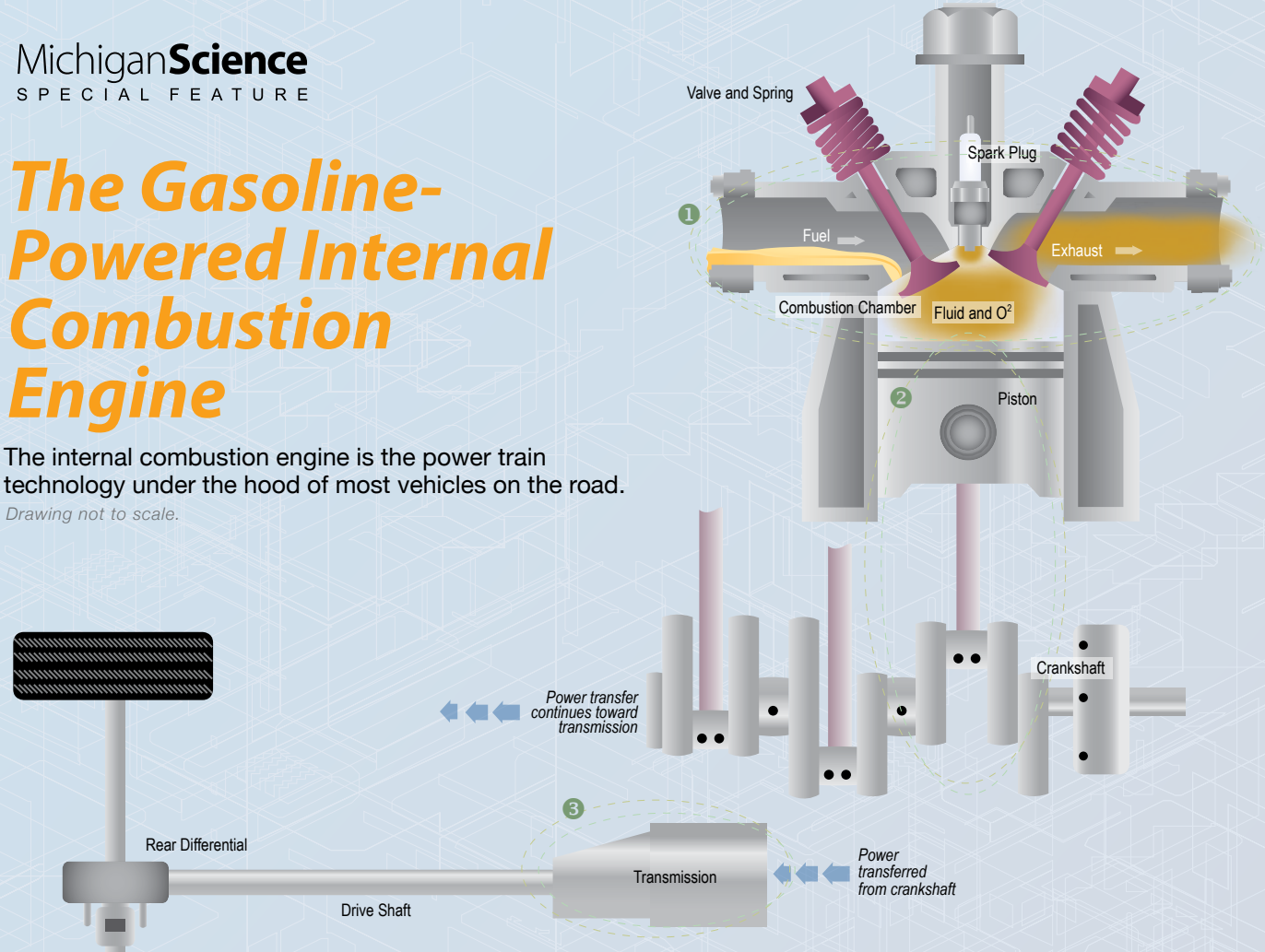
9 National Research Council, page 15.

10 At 5 parts per million, the U.S. diesel emissions standard adopted in 2006 is the strictest in the world. By contrast, the European standard is 50 ppm. Automakers were hesitant to introduce new diesel engines into the U.S. market until a standard was adopted. Volkswagen, for example, introduced a direct injection diesel to the U.S. market, but was forced to withdraw it because it did not meet the new emissions standard. The 5 ppm standard gave automotive engineers a target to shoot for, however, and Volkswagen and other manufacturers plan to bring direct-injection diesels to the U.S. market as early as next year.

The Gasoline-Powered Internal Combustion Engine

The internal combustion engine is the power train technology under the hood of most vehicles on the road.

Drawing not to scale.



❶ In the internal combustion engine, a fuel and oxygen mixture is ignited in combustion chambers, which convert the fuel from a liquid to a gas. The process generates enough heat to expand the gas, which in turn applies pressure to the pistons in each cylinder.

❷ The up-and-down movement of the pistons inside their cylinder pushes down on the engine's crankshaft, which converts the force into a rotary movement.

❸ This rotary movement is applied to the transmission, which transmits energy to the vehicle's drive train.

In most vehicles powered by internal combustion engines, the combustible fuel is petroleum-based gasoline or diesel. Once the fuel is combusted into a gas, it is discharged through exhaust valves.

The full benefits of recent technological advances have yet to be realized. For example, fuel savings of 3 percent to 6 percent are expected from cylinder deactivation, in which some cylinder valves in V-8 and V-12 engines are closed to prevent fuel injection when the car no longer requires acceleration. Even greater efficiency gains — from 5 percent to 10 percent — are expected from variable valve lift and timing, which more precisely regulate the oxygen/fuel mixtures injected into an engine's cylinders.

Advancements in "supercharging" also could improve fuel consumption by 5 percent to 7 percent. Increasing accelerating power (torque) can increase fuel efficiency because it takes more energy and, therefore, more fuel for a vehicle to accelerate than it does to cruise.

New transmission technologies are also emerging, including the five-speed automatic and the continuously variable transmission. A five-speed automatic allows an engine to work more efficiently because the additional gear requires less energy from the engine, thereby improving fuel consumption by 2

percent to 3 percent. The CVT can reduce fuel use up to 8 percent by varying the energy supplied to the drive train depending on driving conditions.

Advances in tire and wheel manufacturing are expected to reduce the rolling friction that occurs between the vehicle and the road. Reducing rolling friction is projected to increase fuel efficiency by up to 1.5 percent.

The gains in fuel efficiency from re-engineering will take time to achieve because of the development cycle of new models. According to the National Research Council:

> The widespread penetration of even existing technologies will probably require four to eight years. For emerging technologies that require additional research and development, this time lag can be considerably longer. In addition, considerably more time is required to replace the existing vehicle fleet (on the order of 200 million vehicles) with new, more efficient vehicles. Thus, while there would be incremental gains each year as improved vehicles enter the fleet, major changes in the transportation sector's fuel consumption will require decades.[11]

Automakers also are engineering alternative-fuel vehicles. Hybrid vehicles, for example, combine a gasoline-powered engine and an electric motor. The gasoline engine is used for acceleration, after which the electric motor kicks in. The electric motor is powered by batteries that are recharged, in part, through the process of "regenerative braking." Regenerative braking involves capturing the friction between the wheels and the brake pads of a decelerating vehicle, and converting that energy into electricity for battery storage.

The Chevy Volt, a General Motors Corp. concept vehicle, uses an electric motor to power the wheels and a small gas engine to charge the generator. The Volt is said to travel 40 miles per hour on electricity alone, while conventional hybrids switch to the gasoline engine when the vehicle speed exceeds 25 mph.

GM announced in May that it would begin production of the Volt by 2010, although the vehicle will require development of new lithium ion battery technology.

Ultimately, GM is engineering the Volt platform to take a hydrogen fuel cell. Hydrogen promises three times the energy content of gasoline per gallon, and the only tailpipe emission is water. Current hydrogen concept vehicles include Honda's FCX and the BMW 7 series. But there remain complex challenges to overcome before mass production of such vehicles can occur. Extracting hydrogen from water by electrolysis is currently a hugely energy-intensive process. Nonetheless, Larry Burns, GM's head of research and development, recently expressed confidence that the company will mass-produce hydrogen-cell vehicles by 2020.

"Clean diesel" technology is another alternative for improving fuel economy. The soot-belching diesels of years past have been replaced by turbocharged direct-injection technology that makes new diesels significantly cleaner and more powerful. In general, they improve fuel efficiency by 30 percent. They also cost less than hybrids. In Europe — where gasoline prices hover above $7 a gallon — diesel-powered vehicles comprise more than 50 percent of the new car market.

"Flex-fuel" vehicles also are coming to market. They can run on conventional gasoline or E85, a mixture of 85 percent ethanol and 15 percent gasoline. U.S. cars made after 1990 can use E10 ethanol without any modifications. But because E85 is more corrosive than gasoline, it requires a specially designed fuel system and additional fuel sensors to ensure a clean burn.

Price shocks at the gas pump, environmental awareness and concerns about U.S. reliance on foreign oil are driving demand for fuel efficiency improvements. But even absent stricter federal mandates, significant improvements in fuel economy already are in the pipeline, with more efficient vehicles comprising a growing share of the nation's fleet. ■

11 National Research Council, p. 5.

By Bruce Edward Walker

Contest Winner Takes on Disney

"Little Mermaid" Exposed as Scientific Fallacy

Genna Greenberger, a 15-year-old student at Portage Central High School, will receive a $500 scholarship from MichiganScience for her winning submission to our "Scientific or Not?" essay contest. Her essay, titled "Under the Sea," describes why the Disney animated feature "The Little Mermaid" defies the laws of science.

The contest required students in grades 6 through 12 to analyze in 500 words a scientific fact or fallacy from a book, movie, song or other pop-culture medium. The contest was sponsored by MichiganScience and Edmund Scientifics®, a premier supplier of science kits and other educational materials.

"At the bottom of the ocean, mermaids should implode from water pressure, making the movie 'The Little Mermaid' scientifically impossible," Greenberger concluded. "Sebastian the Crab couldn't live on the bottom of the sea, either. Sebastian's crustaceous exoskeleton would snap and be crushed under the pressure that far underwater." Greenberger's essay appears on the opposite page.

Genna Greenberger

Greenberger learned of the contest from Cheryl Hach, a teacher at the Kalamazoo Area Mathematics and Science Center. Greenberger relied on the Internet for most of her research.

"I found a good school-use Web site that had a lot of diagrams and helpful information to understand the differences between air pressure and water pressure," she said. "I had no idea that water pressure is so enormous."

Science likely will figure in Greenberger's future. "Science really is interesting," she said. "There are so many little things you need to learn in order to understand the Big Ideas … to learn just how complex and perfect things need to be in order to work [such as] the human body and the Earth."

Greenberger is considering a career in either neonatology or meteorology. "Both interest me a lot," she said. "I would really like to do something with the human body that could help people." The desire to help also motivates her interest in meteorology. "A meteorologist informs people and helps them to prepare for things."

Two other students from Portage Central High School also were named as contest winners. Second place was awarded to Alisha Kamboj for her essay on the scientific errors in the film "The Day After Tomorrow," which depicted the supposed cataclysmic consequences of global climate change. Third place was awarded to Phoebe Huberty, who analyzed why the Fizzy Lifting Drink featured in "Charlie and the Chocolate Factory" could not have lifted the young Charlie and his grandfather into the air. Kamboj and Huberty will receive gift certificates redeemable for science kits and games through Edmund Scientifics®.

A new essay contest will be announced in the next issue of MichiganScience. To read the second- and third-place essays as well as a list of honorable mentions, visit www.MichiganScienceOnline.org. ■

By Genna Greenberger

Science Fictions Under the Sea

In Walt Disney's "The Little Mermaid," many mermaids swim throughout the deepest depths of the bluest oceans. They glide along the colorful coral and swim with dolphins at the bottom of the ocean. According to Sebastian the Crab, life is better "under the sea." This may be true for some sea life, but not for mermaids. At the bottom of the oceans, mermaids should implode from water pressure, making "The Little Mermaid" scientifically impossible.

One major issue facing marine biologists is the inability to reach the bottom of the ocean. This also should affect the mermaids in "The Little Mermaid." Ariel seems to have no crushed bones or compressed organs when she glides along the sea floor. Assuming she has a human skeletal system, there is no way she can swim to the bottom of the sea, where 33 feet of water creates the same amount of pressure as 1.5 million feet of air. The human body is accustomed to ≈14.7 pounds per square inch (psi) of pressure at the Earth's surface. Water is 800 times denser than air, so Ariel couldn't travel to the bottom of the ocean. The only way this would be possible is if her body was more "watery" so she could acclimate to the additional pressure.

At a depth of 1,000 feet, the water pressure is 400 psi. Scuba divers can only dive to a depth of 200 feet, so there is no way a mermaid could swim to the bottom of the sea. Most seas have an average depth of more than 200 feet.[1] The water pressure would be too great for Ariel, her family and all of the other mermaids to live at the bottom of the sea.

The water pressure would be too heavy for most of her sea friends, too. For example, Sebastian the Crab couldn't live on the bottom of the sea, either. Sebastian's crustaceous exoskeleton would snap

and be crushed under the water pressure that far down. His skeleton would last longer than that of the mermaids, but it would still be crushed under the extremely high water pressure. Also, unless the fish adapted to a lack of light and the water pressure, they would not be able to survive.

The higher the amount of water in a body, the more pressure a body can withstand. The mermaids' friends would have to become more "watery." To gain this trait could take thousands of years of evolution.

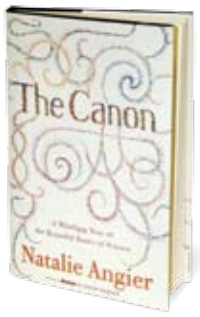
In conclusion, "The Little Mermaid" is scientifically impossible not only because mermaids do not exist, but also because it would be nearly impossible to find most of Ariel's friends that far under the sea. The extreme water pressure crushes thin-boned or "dry" animals. ■

1 Floating Classroom, "Don't Pressure Me! Air & Water Pressure," June 2006. Retrieved on May 31, 2007 from: http://floatingclassroom.tamu.edu/TrainingInfo/Pressure.pdf.

Review by Todd K. Slisher

The Canon: A Whirligig Tour of the Beautiful Basics of Science

by Natalie Angier



Natalie Angier is an experienced science writer for The New York Times who spent part of her youth in New Buffalo, Mich., and who wrote for the Michigan Daily while attending the University of Michigan. She also is the winner of a Pulitzer Prize and numerous other honors. As the title suggests, her latest book is not an exhaustive examination of science, but instead touches on some of the primary principles in physics, chemistry, biology, geology and astronomy.

The tone of Angier's book is conversational, and it is littered with references to popular culture, along with occasional jokes and puns. The book is aimed at adults who, in their younger years, may have dismissed science as boring or incomprehensible, but who are now wiser and willing to give it a second look.

The opening sections of the book cover how the scientific process works and how scientists think. These sections convey to the reader that science is not just facts, but a process. Also included are informative sections on probability and calibration, with the latter featuring the author's own "powers of 10" journey from the subatomic to the universal.

The book briefly covers key concepts of physics, chemistry, evolutionary and molecular biology, geology and astronomy. It also contains many ideas for presenting material that would be valuable to educators attempting to explain science phenomena.

Readers with a background in science may find Angier's approach a bit tedious. She also comes close to anthropomorphism, as evidenced in the following discussion on ionic bonds:

> Consider, then, the lovely symmetry of salt. On one side we have sodium, a soft metal with the silvery sheen of herring scales. Sodium has eleven electrons, two in the innermost orbit, eight in the next, and, in orbit number three, a solitary sailor with a distinct propensity for jumping ship. Across the aisle, we see chlorine, a corrosive, greenish yellow gas. The outer shell of chlorine, as I mentioned earlier, is one electron shy of satiety, and so chlorine leans toward mean, toward stealing electrons where it can.

At many points in the book, Angier's style is both amusing and enlightening, reflecting her degree in English literature (with minors in physics and astronomy) from Barnard College in New York City. But there are times that her prose falls flat and readers may become bogged down by her somewhat meandering style. Some concepts are simply better suited to charts and diagrams. Certainly, no one could compare this to a dry textbook, but her liberal use of pop culture references can sometimes confuse readers who may not be familiar with, say, 1960s situation comedies: "Quantity notwithstanding, a genuine quantum leap is qualitatively spectacular, a bit of 'Bewitched' without the insufferable husband."

The first chapter is among the best in the book. It contains material from Angier's interviews with leading scientists, including Scott Strobel, Deborah Nolan, Donald Sadoway, David Wake, Kip Hodges, Cynthia Wolberger and other brilliant minds at some of the nation's foremost universities. These conversations yield nuggets of insight.

Particularly enjoyable is Strobel's contention that the game Mastermind is "a microcosm for how science works":

> In Mastermind, he explains, you try to divine your opponent's hidden sequence of four colored pegs by shuffling your own colored pegs among peg holes. If you guess a correct color in the correct position, your opponent inserts a black peg on his side of the board; a correct color in an incorrect position gets you a white peg; and the wrong color for any position earns you no peg at all. Your goal is to end up with four black pegs on your adversary's end in as few rounds as possible.
>
> 'If you're trying to pose a question in a way that gets you data you can interpret, you want to isolate a variable,' Strobel says. 'In science we take great pains to design experiments that ask only one question at a time. You isolate a single variable, and then you see what happens when you change that variable alone, while doing your best to keep everything else in the experiment unchanged.'

Angier's book is a good read — one that would appeal to those with a passing interest in science rather than those steeped in it. The latter reader, however, would enjoy her interviews and enthusiasm for science despite the lack of depth. At worst, science-types just might learn some new techniques for making themselves understood when talking to the rest of us. ■

Looking Ahead

By Russ Harding

Lawmakers' focus on budget issues this session has resulted in little action on environmental issues. However, that is likely to change once the Legislature finalizes the 2008 budget. Several environment-related bills are awaiting debate, including the following:

CLEANUP STANDARDS

Debate is expected later this year on streamlining the process required to remediate contaminated property. A major point of contention centers on the criteria used to determine when a cleanup is complete. Developers argue that once they have met DEQ requirements they should be free of future liability; the agency wants to retain the authority to require further cleanup if conditions change or additional information is revealed.

REGULATING CONCENTRATED ANIMAL FEEDING OPERATIONS

The regulation of farms where livestock and poultry are confined in buildings has become a contentious issue. Concentrated Animal Feeding Operations are currently regulated under the Clean Water Act because of potential discharges to waterways. The Michigan Farm Bureau and its allies are advocating the adoption of a permitting system based on compliance with "best management practices." A five-year pilot project testing such a system ends in December, and a final report on its efficacy will be issued. Environmental groups contend that the pollution discharge permits are still necessary to protect water quality.

SURCHARGE ON SOLID WASTE

House Bills 4221 and 4222 would impose a surcharge of $7.50 per ton for solid waste deposited in Michigan landfills. The resulting revenue would fund recycling and litter education programs. Proponents argue that Michigan has a lower recycling rate than surrounding states and that the surcharge would promote recycling while deterring the importation of Canadian waste. Opponents contend that the surcharge would be an illegal tax. Opponents also say this "tax" would hurt Michigan's economy by driving up trash disposal costs and it would not reduce shipments of Canadian trash because existing contracts with landfills are still in force.

REGULATORY FEE INCREASE

The Michigan Department of Environmental Quality is seeking to increase regulatory fees by a total of nearly $19.6 million, including the costs of permits for air emissions, wetlands, dam safety, floodplains, inland lakes and streams and groundwater discharge. The agency also wants to impose higher fees for pollution prevention, hazardous waste disposal, solid waste, on-site sewage and mineral wells. The existing fees generate $22.6 million annually. If approved, the fees would total $42.2 million — an increase of 87 percent. The agency claims higher fees are necessary to make up for less federal and state funding of regulatory programs. However, the regulated community will likely resist the higher fees given the economic challenges facing Michigan businesses. More information can be found at MichiganVotes, www.michiganvotes.org; search Senate Bill 406.

GREAT LAKES WATER QUALITY AGREEMENT

State Sen. Patricia Birkholz (R-Saugatuck Township) has introduced legislation that would implement the Great Lakes Water Quality Agreement in Michigan. In order for the agreement to be binding, all Great Lakes states must pass implementing legislation. To date, only Minnesota has passed such a statue. The agreement requires, in part, state regulation of new or increased water withdrawals within five years of ratification. The agreement prohibits out-of-basin withdrawals, but exempts communities that straddle the basin. More information can be found at MichiganVotes, www.michiganvotes.org; search House Bill 4336, House Bill 4343 and Senate Bill 212. ■

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