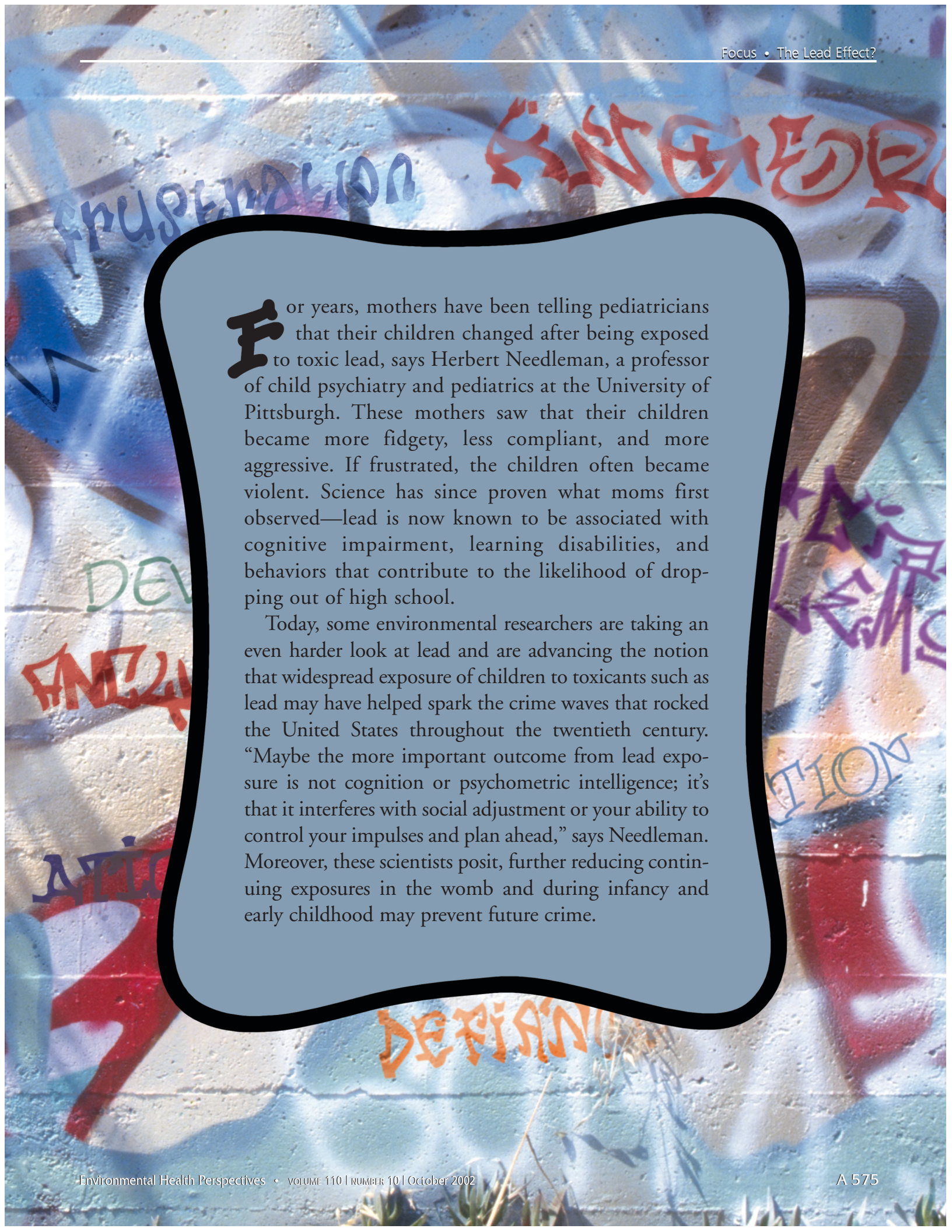


THE LEAD EFFECT?





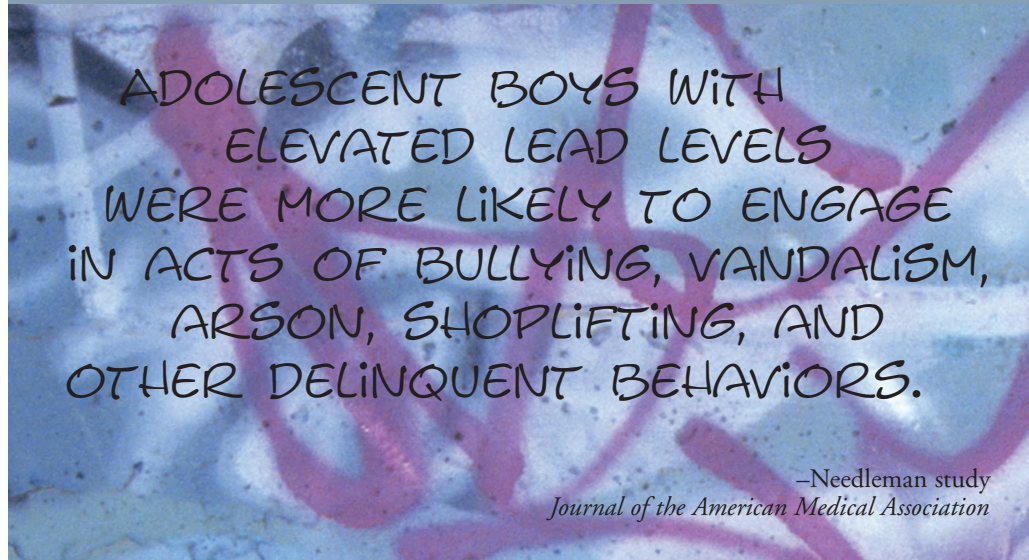
For years, mothers have been telling pediatricians that their children changed after being exposed to toxic lead, says Herbert Needleman, a professor of child psychiatry and pediatrics at the University of Pittsburgh. These mothers saw that their children became more fidgety, less compliant, and more aggressive. If frustrated, the children often became violent. Science has since proven what moms first observed—lead is now known to be associated with cognitive impairment, learning disabilities, and behaviors that contribute to the likelihood of dropping out of high school.

Today, some environmental researchers are taking an even harder look at lead and are advancing the notion that widespread exposure of children to toxicants such as lead may have helped spark the crime waves that rocked the United States throughout the twentieth century. “Maybe the more important outcome from lead exposure is not cognition or psychometric intelligence; it’s that it interferes with social adjustment or your ability to control your impulses and plan ahead,” says Needleman. Moreover, these scientists posit, further reducing continuing exposures in the womb and during infancy and early childhood may prevent future crime.

Needleman has long been at the forefront of the debate over a possible relationship between childhood lead exposure and the development of juvenile delinquency and a propensity to commit criminal acts. Evidence that lead poisoning induces severe behavioral problems has been around for decades. Today, however, Needleman and

nile delinquency among 195 inner-city youth in Cincinnati. Blood lead levels were sampled before birth and through adolescence. Published in the November/December 2001 issue of *Neurotoxicology and Teratology*, it's the first long-term study to track lead exposure in children from womb to mid-adolescence.

in both cognitive and behavioral function, including aggressiveness, impulsiveness, and ability to pay attention," says Ted Schettler, science director of the Science and Environmental Health Network, an environmental and public health policy think tank. "Whether they translate into crime is another matter."



ADOLESCENT BOYS WITH ELEVATED LEAD LEVELS WERE MORE LIKELY TO ENGAGE IN ACTS OF BULLYING, VANDALISM, ARSON, SHOPLIFTING, AND OTHER DELINQUENT BEHAVIORS.

—Needleman study
Journal of the American Medical Association

other researchers are building a stronger case for behavioral effects at relatively low levels of exposure. The past decade has produced a series of intriguing findings.

A study of some 300 Pittsburgh students, led by Needleman and published in the 7 February 1996 issue of the *Journal of the American Medical Association*, first revealed that adolescent boys with elevated lead levels were more likely to engage in acts of bullying, vandalism, arson, shoplifting, and other delinquent behaviors, according to self and parental reports.

In their latest work, presented at the 2000 joint conference of the American Academy of Pediatrics and Pediatric Academic Societies in Boston, Needleman's team used X-ray fluorescence technology to examine bone lead concentrations in roughly 350 youngsters aged 12–18 in Allegheny County, Pennsylvania, to gauge past exposures. The team found significantly higher bone lead levels in children convicted of delinquency than in those with no juvenile convictions. Among boys, convicted delinquents were almost twice as likely to have higher bone lead concentrations, Needleman reports, and four times as likely after adjusting for confounding factors.

Last year, Kim Dietrich, a developmental psychologist and professor of environmental health and pediatrics at the University of Cincinnati College of Medicine, reported a significant link between prenatal and other early exposures to lead and self-reported juve-

"There appears to be a linear relationship between blood lead levels and the number of reported delinquent acts from the lowest levels of exposure to the highest," Dietrich says. Interestingly, the team found no gender difference in the correlation. Exposed girls were as likely as boys to commit delinquent acts, despite the fact that male gender is almost always a risk factor for engagement in delinquent behavior.

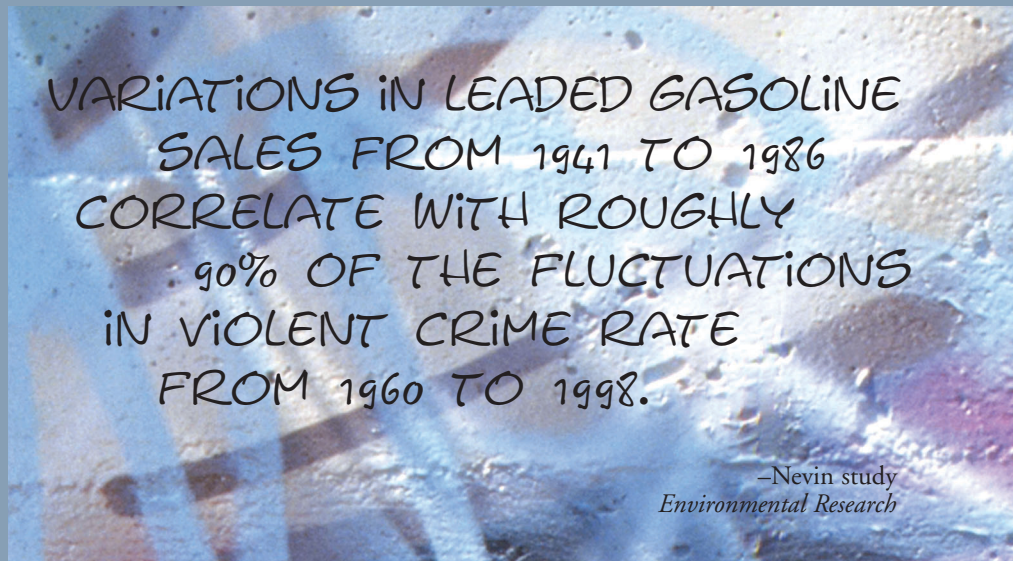
Intriguing as these findings are, there is still skepticism over whether lead exposure really contributes to delinquency. "There's no disagreement that lead can cause changes

A History of Prior Bad Acts

Today, the chief source of lead exposure for American children is through ingestion or inhalation of deteriorating lead paint in older housing. Use of lead in house paint peaked in 1914 and was banned in 1978. According to the Department of Housing and Urban Development (HUD), lead paint coats surfaces in 39 million homes, or 40% of the nation's entire housing stock. HUD estimates that, of those homes, lead paint hazards lurk in about 25 million, more than one-fifth of which are currently occupied by a child under the age of 6.

Lead was first introduced to gasoline in the mid-1920s, after a General Motors scientist discovered its octane-boosting effects. Tetraethyl lead may have been an inexpensive octane enhancer, but it also proved a particularly pernicious pollutant because of its neurodevelopmental effects and its indefinite persistence in the environment.

Before its phaseout under the Clean Air Act beginning in the late 1970s, lead in gasoline was the greatest source of exposure; indeed, leaded gas made the toxicant essentially ubiquitous in the environment. In 1976, nearly 90% of U.S. children aged 1–5 had blood lead levels exceeding the 10 µg/dL guideline set by the Centers for Disease Control and Prevention (CDC). After lead's phaseout from gasoline, the mean concentration dropped across all demographic groups in the entire popula-



VARIATIONS IN LEADED GASOLINE SALES FROM 1941 TO 1986 CORRELATE WITH ROUGHLY 90% OF THE FLUCTUATIONS IN VIOLENT CRIME RATE FROM 1960 TO 1998.

—Nevin study
Environmental Research

tion uniformly from 16 µg/dL in 1976 to 2 µg/dL by 1999. By 1990, 90% of U.S. children aged 1–5 met the CDC guidelines, according to data from the National Health and Nutrition Examination Survey.

Even levels below the 10 µg/dL CDC threshold are reported to still have health effects, including lowering IQ and causing behavioral problems. A team led by Bruce Lanphear at Children's Hospital Medical Center in Cincinnati reported at the 2000 joint conference of the American Academy of Pediatrics and Pediatric Academic Societies that cognitive defects in reading, math, short-term memory, and visual construction skills occur at levels as low as 2.5 µg/dL.

Developmental exposures to lead, depending on the time and level of the exposure, have exhibited a variety of effects on the brain on a mechanistic level, including detectable structural changes. But researchers have yet to pin down a direct mechanism that might contribute to the development of delinquent behavior. "Lead does so much damage, it's hard to decide what is the important factor," Needleman explains. Plus, neurologists still don't understand the neurophysiological basis for delinquent behavior of any type. Some behaviorists have suggested that lead's adverse effects on parts of the brain that control behaviors such as aggressiveness may be a possible route. For example, lead's ability to impair function of the prefrontal lobe, where impulsivity is regulated, may be a factor, Needleman says.

Nature, Nurture, or Both?

Scientists agree that lead exposure is associated with decreased IQ. The general consensus is that for every increase in blood lead of 4 µg/dL, there is a 1-point drop in IQ. Although there's a long history in the psychological literature of studies documenting relationships between IQ and criminality, debate still rages over whether it is lead's effects on IQ or its effects on psychosocial function that are the more important factors contributing to delinquency. What's especially controversial is the question of how


much of the variance is attributable to genetics and how much to environment.

"Lead's links with aggression, impulsive behavior, and attention loss are pretty clear, and that sets a kid up to have problems in school," Schettler explains. Although such effects themselves add to the risk of running into trouble with the law, struggling students tend to drop out or not pursue higher education, making it tougher to land high-paying or interesting jobs, he says. "And you start putting that together with all the other social factors, and it's very possible there's a link with delinquent behavior and crime at some point that's very plausible," Schettler says. "Who knows whether there are two, three, or more steps in that cascade."

Philip Landrigan, chair of community and preventive medicine at Mount Sinai School of Medicine, points out that just because a child is exposed to lead doesn't

University of Rochester, "The effect of lead is much greater on kids from lower-income families. If you're dealing with a disadvantaged population that already has a lower mean IQ and you expose that population to a neurotoxicant, especially a developmental neurotoxicant, you will find the effect amplified, which means you have to think about effect modification."

In many ways, says Weiss, by stripping away confounding factors, what science has done is to focus too intensely on one set of risks when there are multiple risks whose interactions might provoke even greater adverse effects. "It's not just certain disadvantaged populations that suffer higher exposures to lead, because we know that minority kids have higher levels," he says. "But in general, because of their social and economic circumstances, they also are exposed to other kinds of risks that might



THERE'S NO DISAGREEMENT THAT LEAD CAN CAUSE CHANGES IN BOTH COGNITIVE AND BEHAVIORAL FUNCTION, INCLUDING AGGRESSIVENESS, IMPULSIVENESS, AND ABILITY TO PAY ATTENTION. . . . WHETHER THEY TRANSLATE INTO CRIME IS ANOTHER MATTER.

—Ted Schettler
Science and Environmental Health Network

guarantee that the child will end up going to jail or being a criminal, although it may increase the risk. "That injury which is done to the brain of a child early in life by lead sets the stage for the child possibly becoming delinquent or criminal when the child gets older," he says. "But whether the child actually goes on to become delinquent or criminal depends on other factors as well. It depends upon the family structure, the school, the community, the whole psychological environment in which the child grows up."

In fact, many researchers believe the impacts of lead on criminal behavior work synergistically not only with other social risk factors but with other detrimental effects of lead exposure, such as impaired learning abilities. For example, says Bernard Weiss, a professor of environmental medicine and pediatrics at the

add to or multiply the kinds of risks that are posed by lead exposure or other kinds of toxicant exposure."

In such debates, proving a direct link remains a challenge. "The easiest part is identifying association; it's most difficult going from association to a pure cause-and-effect relationship," acknowledges Bailus Walker, a professor of environmental and occupational medicine at Howard University School of Medicine. Frequently, however, the standard of proof is politicized. Studies that might prove an effect have never been done, or the bar is set so high by skeptics that a link will never be demonstrated. Yet Walker admits, "Our current epidemiological tools may not be sharp enough to advance our understanding there. Perhaps if we went to the molecular level, that might help us really understand this issue much better."

Researchers can currently only speculate on mediating neurobehavioral factors such as academic skills and self-regulatory ability, which are also under examination. To test theories on how lead's disruption of brain pathways and mechanisms contributes to antisocial behavior, studies using magnetic resonance imaging and magnetic resonance spectroscopy are under way to identify regions of abnormal brain functioning in members of Dietrich's Cincinnati cohort. According to one such theory, set forth in the 1995 World Health Organization report *Environmental Health Criteria 165: Inorganic Lead*, early exposure to lead may lower levels of serotonin and enhance dopamine sensitivity. Such neurotransmitters are involved in mediating responses to external stimuli.

Some researchers have raised concerns about the limitations of X-ray bone spec-

delinquent, which is a risk factor for delinquency. "Parent variables are crucial in their association with later behavioral problems," Kaufman says. "[The studies] left uncontrolled what potentially is the most important variable." Although Kaufman believes "this is a totally fruitful topic to be researched," he asserts that "much has been made over little evidence. More credence needs to be given to the parents' role."

But Dietrich and Needleman maintain that the recent studies do use controls for myriad confounding factors, including parental intelligence, the quality of caregiving throughout infancy and early childhood, and socioeconomic status, among others. "The majority of the parents of the teens in my study grew up in the same lead-contaminated housing as their offspring," Dietrich says. "Lead undoubtedly played an adverse role in [the parents'] neurodevelopment as well."

rate variations between 1900 and 1960, possibly explaining about 70% of the change, the study found. A lag effect of 18–23 years—basically the time it takes an exposed child to grow up—was documented, depending on the specific crime.

"I'm absolutely convinced the incredibly sharp decline in violent crime we've seen all across the country since 1990 is a reflection of the sharp decline in childhood lead exposure that began in the early 1970s and accelerated after 1980," says Nevin. "It just starts to become undeniable that there's a very strong relationship. . . . It is so horrifying that childhood lead exposure could explain that much of the variation in violent crime."

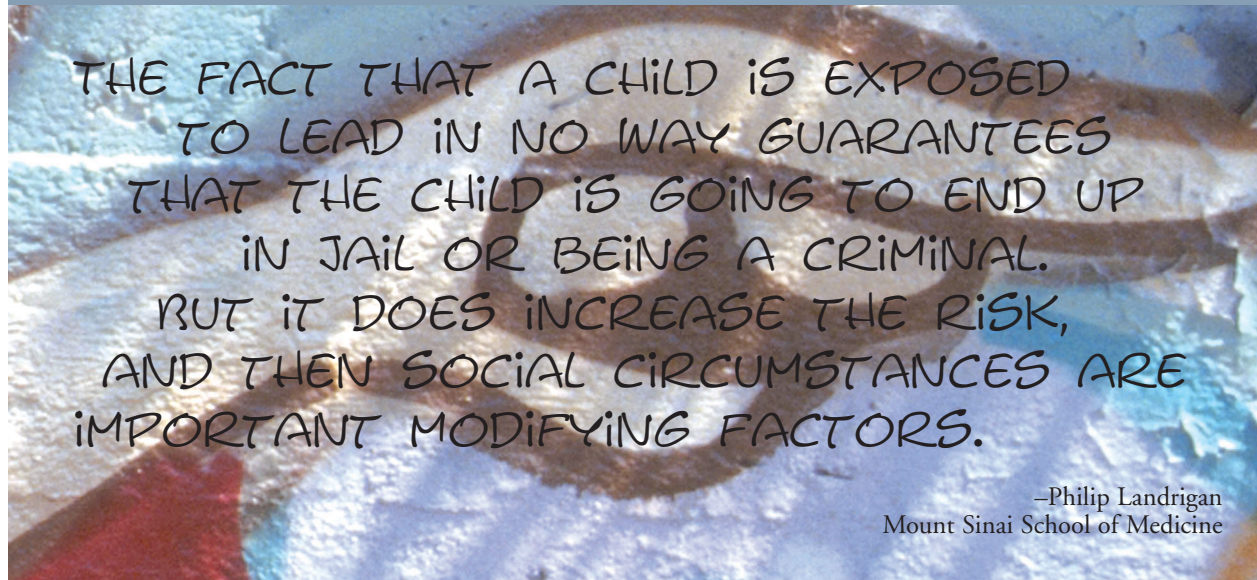
Nevin's continuing work is finding a similar association between trends in violent crime and leaded gas sales in a dozen other industrialized countries. A more refined analysis of the available data on lead exposure

from paint may explain variations in murder rates in America's largest cities during the period 1979–1991, when the U.S. murder rate hit its peak.

However, the consensus of the research community is that, although Nevin's work is interesting and invites further study, it isn't nearly as solid scientifically as the case-control studies of Dietrich, Needleman, and others. In addition, although Nevin attempted to factor in everything from unemployment trends to teen

birth rates, controlling for important variables at the national, regional, and local levels over decades is no easy task.

But additional environmental evidence is being tabulated. A study published in the May 2001 issue of the *Archives of Pediatrics and Adolescent Medicine* found a link between high concentrations of lead in the air and higher homicide rates. Sociologist Paul Stretesky of Colorado State University in Fort Collins and criminologist Michael Lynch of the University of South Florida in Tampa examined 1990 U.S. Environmental Protection Agency data from 3,111 counties in the United States and found that the counties with the highest air lead concentrations had homicide rates nearly four times higher than counties with the lowest levels, after adjusting for 15 confounding variables. When the agency releases the next round of air data, for 2000, the scientists will take



THE FACT THAT A CHILD IS EXPOSED TO LEAD IN NO WAY GUARANTEES THAT THE CHILD IS GOING TO END UP IN JAIL OR BEING A CRIMINAL. BUT IT DOES INCREASE THE RISK, AND THEN SOCIAL CIRCUMSTANCES ARE IMPORTANT MODIFYING FACTORS.

—Philip Landrigan
Mount Sinai School of Medicine

troscopy, used in many of the studies, given its status as an experimental technique. "We're not at a point where we can take a bone lead concentration measurement and say what [the subject's] blood lead level history was over time," Dietrich explains. But in many circles, X-ray bone spectroscopy is gaining ground on the blood lead level test as the standard for assessing exposure. It offers the best potential for getting a retrospective picture of exposures, Dietrich says, because lead only stays in the bloodstream for a month or two after an exposure, but is deposited in bone, where it remains for decades.

Alan S. Kaufman, a clinical professor of psychology at Yale University School of Medicine, contends that existing studies neglected to control for generational relationships of social dysfunction, such as whether a child's parents were themselves

Ecologic Evidence

Meanwhile, ecologists and social theorists are adding fuel to the fire. In a recent examination of data from the 1900s, researchers found a correlation between the amount of lead released into the environment from auto exhaust and paint, and violent crime, including rape, robbery, assault, and murder. The study was published in the May 2000 issue of *Environmental Research*, and was conducted by Rick Nevin, vice president of ICF Consulting (a housing and environmental health issues firm in Fairfax, Virginia) under contract to HUD.

According to the study, variations in leaded gasoline sales from 1941 to 1986 correlate with roughly 90% of the fluctuations in violent crime rates from 1960 to 1998. Variations in predicted childhood lead exposure from the use of lead paint between 1879 and 1940 strongly correlate with murder

another look to see how the same counties are doing.

“As far as crime policies go, it may be important to clean up lead in some parts of the environment, in certain areas in certain parts of cities, to help to reduce crime,” Stretesky says. “I’m convinced that Needleman was on to something when he started looking at this.”

Jessica Wolpaw Reyes, a researcher at Harvard University’s National Bureau of Economic Research,

predicts that the total removal of lead from gasoline under the Clean Air Act may eventually cause a nearly 30% drop in violent crime between 1993 and 2013. Her work also corroborates the strong correlation between the removal of lead from gasoline in the 1970s and reduction in crime in the 1990s. Wolpaw Reyes bases her estimate on an analysis of state-by-state crime and lead exposure data from the past century. Her work, presented in her June 2002 Harvard dissertation, awaits peer review and publication.

The Power—and Price—of Prevention

Despite successes in lead abatement, much work remains. Tragically, hundreds of thousands of children continue to be exposed at substantial levels in the United States.

THERE STILL ARE POCKETS IN UNDER-RESOURCED COMMUNITIES, TYPICALLY MINORITY AND LOW-INCOME COMMUNITIES, WHERE LEAD EXPOSURE CONTINUES TO BE A PROBLEM. . . . THESE AT-RISK POPULATIONS USUALLY AREN'T A POWERFUL POLITICAL FORCE, SO THEY ARE OFTEN OVERLOOKED BY POLICY MAKERS.

—Bailus Walker
Howard University School of Medicine

Roughly 890,000 youngsters aged 1–5 are estimated to still have blood lead levels at or above 10 µg/dL, though new estimates are expected from the CDC this fall. African-American children are five times as likely as Caucasian children to be overexposed.

“There still are pockets in under-resourced communities, typically minority and low-income communities, where lead exposure continues to be a problem,” Walker says. “These at-risk populations usually aren’t a powerful political force, so they are often overlooked by policy makers.”

“We’re still not adequately screening the population so that we’re picking up all of the kids that are lead-exposed,” Schettler says. Furthermore, says Don Ryan, executive director of the Alliance to End Childhood Lead Poisoning, an advocacy group, “We wait until children are identi-

fied with symptoms to take any action, and even then the action is half-hearted, ineffective, and of course too late.”

Chelation therapy is currently the standard treatment for lead poisoning. The treatment uses a chemical such as succimer that binds lead in the blood so it may then be excreted. Although chelation therapy removes lead from the blood, a study led by NIEHS epidemiologist Water Rogan and published in the 10 May 2001 issue of the *New England Journal of Medicine* reveals that cognitive loss is not restored.

The costs continue to pile up. In a study in the July 2002 issue of *Environmental Health Perspectives*, a team led by Landrigan estimates the total annual health care costs of lead poisoning: a staggering \$43.4 billion a year, or about 2.2% of total U.S. health care costs. The costs include direct treatment costs and also such collateral damage as special education and reduced lifetime learning capacity. “It’s a national scandal,” Landrigan says.

Many advocates are looking to the lead paint industry to bear some of the burden, regardless of whether the companies knew the extent of the hazard at the time the paint was applied. “That’s the big question we as a country have to answer: What is the proper role of the lead paint manufacturers in the equation?” Ryan says.

This fall a jury in the Rhode Island Superior Court will hear a case brought by Rhode Island attorney general

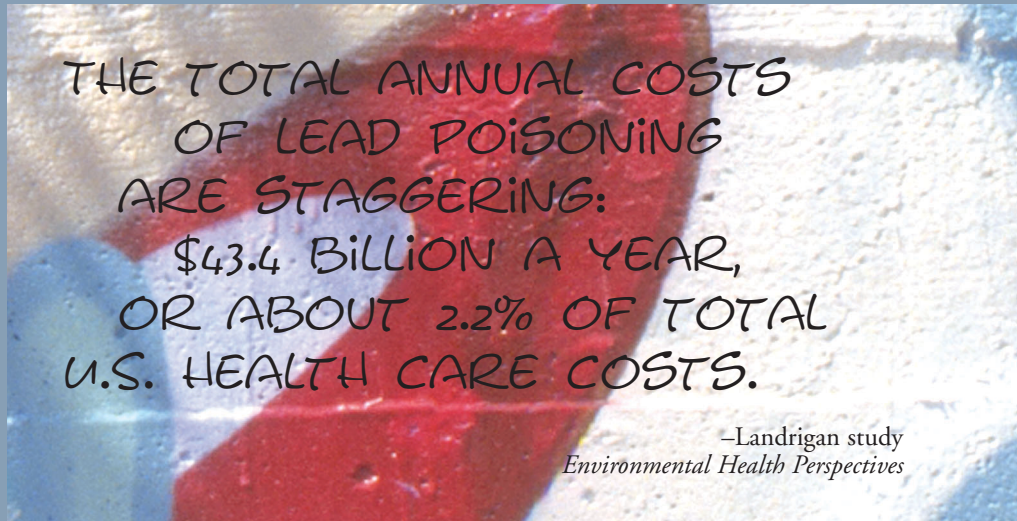
HUD'S CURRENT PROGRAM, WHICH PROVIDES \$115 MILLION IN GRANTS TO REMOVE LEADED PAINT ENTIRELY OR AT LEAST CONTAIN IT OR STOP ITS DETERIORATION, IS ENOUGH TO REMEDIATE LESS THAN 0.1% OF SERIOUSLY DANGEROUS HOUSES.

—Don Ryan
Alliance to End Childhood Lead Poisoning

Sheldon Whitehouse against nine manufacturers of lead paint and their industry association, alleging that the presence of lead paint in buildings constitutes a public nuisance. The case could lead to millions in damages. Similar cases are pending in myriad other states and municipalities. In recent years, several defendants have attempted to use childhood lead poisoning as a defense for murder and other crimes.

For its part, the industry claims it has been scapegoated. An unnamed lead paint industry spokesperson contends that companies were unaware of the potential hazards when the paint was applied. At the time it was used, lead paint was widely touted as a more durable product than competing brands that lacked the metal. “[The opposition is] attempting to twist the facts and the law to make us bear responsibility,” says Tim Hardy, an attorney representing NL Industries, one of the defendants in the Rhode Island case. He points to the fact that industry removed lead from paint designated for interior use 50 years ago as a result of industry-funded studies. However, child advocates point out that this ignores the fact that lead was left in exterior paint for another 25 years, and that exterior paint still posed a threat, by both being used indoors and adding lead to outdoor soil.

Many public health experts and officials contend that the lead industry has a history of going to extremes to suppress data that don’t support its cause. In the 1920s, General Motors influenced investigations into the safety of adding lead to gasoline, despite evidence demonstrating the ill effects of lead at that time. The lead paint industry, likewise, knew that lead paint was seriously neurotoxic to children, but fought against any regulatory effort in the United States for decades, children’s



—Landrigan study
Environmental Health Perspectives

health advocates contend. Landrigan points to an article in the January 2000 issue of the *American Journal of Public Health* by historians Gerald Markowitz of City University of New York and David Rosner of Columbia University, which states that “beginning in the 1920s, the Lead Industries Association and its members conducted an intensive campaign to promote the use of paint containing white lead.” Meanwhile, lead paint was banned in the 1950s in many other countries because the data on its toxicity were so convincing. Even as recently as the early 1990s, lead industry-funded representatives attempted to discredit Needleman’s lead work by promulgating charges of scientific misconduct against him. After an investigation by the Office of Research Integrity, he was cleared of the allegations and exonerated by the scientific community at large.

Lead abatement is generally considered the best strategy to prevent new exposures, but the cost to contain chipping or peeling

lead paint or remove it entirely can cost more than \$10,000 per home. Federal efforts to reduce the number of houses with deteriorating lead paint are making slow progress. HUD’s current program, which provides \$115 million in grants to remove leaded paint entirely or at least contain it or stop its deterioration, is enough to remediate less than 0.1% of seriously dangerous houses, Ryan says. “At that rate, it’s not going to take us ten years but one thousand.”

Property owners are obligated by existing laws to appropriately caution, if not protect, tenants from the hazards of lead. “Groups of landlords complain about the fact that it costs several thousand dollars to remove lead from an apartment,” Landrigan says. “They use that as an excuse for not removing the lead, so children are exposed to the lead year after year after year. But every year we run up billions of more dollars in costs in order to save the landlords relatively trivial amounts of money.”

Regardless of who should pay—the federal government through taxpayers, culpable businesses or property owners, or individuals—one thing is clear, according to Schettler: “The evidence is strong enough that we ought to be doing what we can to remove lead from our environment.” Given that the effects of even short-term exposure to lead appear permanent, prevention of such exposures is key to protecting children, health policy experts contend. And many now believe prevention may also prove key to reducing future crime waves. The result of cleaning up lead contamination and eventually preventing children’s exposure altogether, even before birth, could mean a less violent future for all of us.

Julie Wakefield

KPT

—Don Ryan
Alliance to End Childhood Lead Poisoning