"was almost a complete surprise to us," Somerville says. Nook had expected differentiation to increase with age; instead, it consistently fell to a nadir during adolescence, across many trials.

Two separate effects seem to account for this: "The youngest participants really experienced one emotion at a time. They picked one dominant emotional state that they felt, and it was at the exclusion of the others," Somerville explains. "From childhood to adolescence, people are abandoning the idea that they can experience only one emotion at a time, and they're experiencing groupings of emotions"—but those emotions aren't well differentiated. "And from adolescence into adulthood, people become more granular, more specific about applying emotions to different situations."

These questions may be clinically important because inability to differentiate emotions has been implicated in a wide range of mental illnesses: anxiety disorders, depression, and schizophrenia among them. One explanation might be that in order to manage emotions, a person needs to be able to recognize them as such. "A central issue with many forms of psychopathology is that emotions go awry," Nook points out. And if it's true that emotional granularity reaches a low point among teenagers, this might relate to increased mental-health disorders at that stage.

Difficulty in differentiating emotions, Nook says, might not be a *cause* but a *consequence* of mental illness (or it could be neither—just a correlate of the condition). "It's possible that as people become depressed, their emotions become more complicated, and they struggle to differentiate them." He continues to investigate how people represent emotions in their minds. In a related paper recently submitted for review, he looked at what he calls "emotional abstraction." "Emotion concepts can be represented in very concrete ways or very abstract ways," he explains. "You can ask kids to tell you what 'angry' means, and they'll say, 'I feel angry when my sister steals my toys.' Adults might say, 'Anger is something people feel when their goals are blocked.'"

People tend to define emotions in indirect ways, Nook says: in terms of very specific examples ("when my sister steals my toys"), or closely related or synonymous emotions. Emotion concepts may not be discrete mental states, but a low-resolution way for people to explain how they feel. If that sounds very abstract, Nook has an eye toward clinical applications: "Most of our interventions in mental illness have to do with talking to people about their feelings. So understanding how we can help people represent their emotions through language could be a central way to intervene. We won't be able to get there until we start mapping out some of these questions." ~MARINA BOLOTNIKOVA

SOMERVILLE LAB WEBSITE:
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LIVING LAB

The Brain in the Basement

HOUSEZERO, as the wood-shingled building at 20 Sumner Road in Cambridge is now called, owes the moniker to its efficiency: zero carbon emissions, zero electricity required from the grid, zero electric lighting needed during daylight hours, and zero fossil-fuel-driven heating and cooling. That combination makes this building, which doubles as headquarters for the Center for Green Buildings and Cities (CGBC), a unique example of sustainable retrofitting. But what really sets this sustainability project apart is that the house (now converted to office space for 25 CGBC staff members and researchers) is an expensive test facility—a laboratory—not a model home. Nearly five miles of wiring capture 17 million data points per day to quantify how each of the innovations used in the reconstruction work best. The data flow from two types of sensors. Some are critical to the operation of the building: for example, controlling the system of windows and shades in response to inputs about temperature, rain, wind direction, and indoor CO_2 levels and airflows. Other sensors, purely observational, are intended to generate insights into optimizing the relationship between indoors and outdoors, while maximizing the health and comfort of the building's occupants.

As environmental-control technology has grown more elaborate and complex, explains CGBC founding director and professor of architectural technology Ali Malkawi, more architects and builders have opted to seal structures in order to heat and cool them mechanically. As a result, 42 percent of en-

Solar panels on the roof and fixed shading on the windows suggest that this is no ordinary wood-shingled house.

Photographs by Stu Rosner

HouseZero's front entrance opens to a central staircase lined with acoustic, sound-deadening panels designed at the Graduate School of Design especially for this project. At right is the first floor's main workspace.

ergy consumed in the United States is used to operate buildings—"And the developing world is quickly catching up."

The Graduate School of Design's HouseZero, envisioned as an antidote to this trend, aims to run entirely *without* such conventional systems. To help achieve this, many tons of concrete mass were added in the floors between stories during its renovation, as heat sinks to stabilize daily temperatures from night to day, and seasonally across frigid winters and scorching summers; fixed shading was added to window exteriors; and the existing windows were replaced with new ones that open and close automatically, as directed by a controlling algorithm running on the house's "brain" (a basement computer capable even of integrating weather predictions so the building can prepare for temperature extremes in advance). In summer, for example, the windows, which operate on very little electricity, open at night to cool the space whenever there is a temperature drop of 10 degrees or more, and then close before people arrive in the morning. Basement batteries store power from the photovoltaics on the roof, so the building is expected to cost almost nothing to operate. "The idea," Malkawi says, "is to move away from a mechanical-engineering-dominated world in buildings to this ecological approach." As such, the retrofitted house is a test site for the center's research mission.

To enable researchers to investigate the relative importance of various technologies in the smooth operation of the house, the building has redundant systems such as geothermal heating and cooling equipment in the basement and solar thermal heating apparatus on the roof. Malkawi's aim is to use neither, if possible. Failing that, the fallback (for example, in winter) will be solar thermal heat; geothermal is a distant third option.

It's machine learning for houses: sensors connect to a "brain" that constantly optimizes the environment.

The main research questions, he adds, have nothing do with the specific energy-generation technologies used, because those change and "can be put on and off like a jacket." He wants to know whether an algorithmically controlled building can optimize itself. How would complex building data be used to develop such algorithms? What is the minimum number of sensors needed? And can this approach be deployed at scale?

"We are a research institution," says Malkawi. In analyzing all the data from HouseZero, "The main goal is to generate knowledge and understand what people don't have the capacity to understand now." There are many complexities in understanding building-performance behavior. One of the hardest computational tasks will be adapting to the building's human occupants. "The variables and uncertainties of people's behavior," he says, "are really one of the most complicated things!"

For more information on the CGBC, see harvardmag.com/cgbc-14.

~JONATHAN SHAW

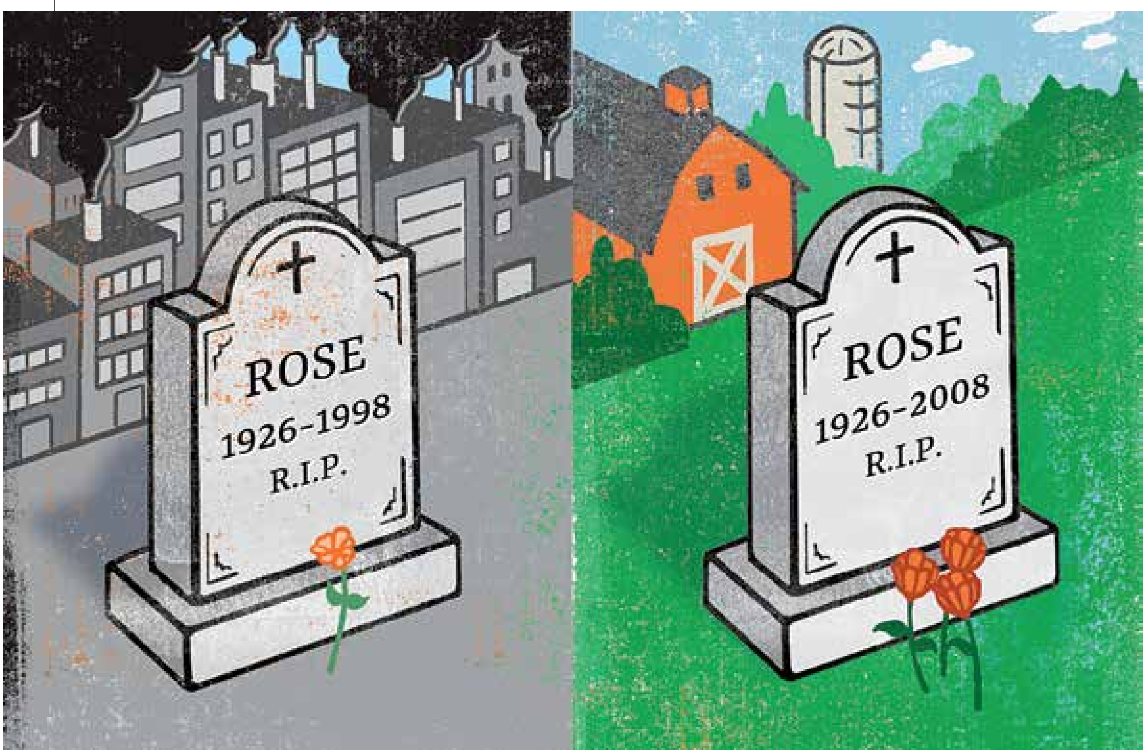
CGBC WEBSITE:
http://harvardcgbc.org

ECHOING EVIDENCE

A Particulate Problem

Twenty-five years ago, a team of eight University researchers famously estimated the critical impact of air pollution on mortality rates across six American cities—findings that came to be known as the Harvard Six Cities Study. Because the researchers were steadfast in keeping confidential the personal health data of the 8,111 Americans who participated in the study, and the findings would prove costly to the operators of fossil-fuel-burning power plants, the work faced aggressive scrutiny from Congress as well as the Environmental Protection Agency (EPA), on the grounds that it used so-called secret science in seeking to influence regulatory decisions. The eventual regulations, based on the study, helped decrease harmful concentrations of fine-particulate matter (particles smaller than 2.5 microns wide, a main source of which is fossil-fuel combustion) in the nation's air, thereby improving public health.

Last June, eight new Harvard-affiliated researchers revisited the study, using new technologies and innovations in statistical analysis and examining Medicare data—the largest and most public dataset available documenting the health of U.S. citizens—thus presumably averting renewed charges of secret science (an issue raised anew by current EPA administrator Scott Pruitt). Their findings breathe new life into the main conclusion of the original Six Cities research: that fine-particulate matter, even in concentrations *below* the current national standards, drives up mortality rates across the country.



Professor of biostatistics Francesca Dominici is one of the 2017 study's lead researchers. The co-director of Harvard's Data Science Initiative explains that quantifying the effects of particulate pollution at levels below national standards poses a unique challenge, comparable to "walking into a clean kitchen and trying to find...the dirty spots that you need to clean. As we try to study lower and lower levels of fine-particulate matter...it becomes increasingly difficult" to find the dirt. But Dominici and her colleagues had time

Illustration by Blair Kelly