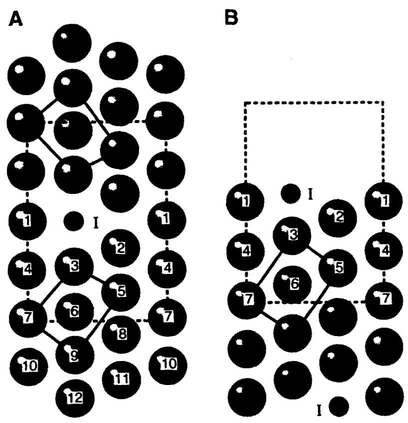
Why steel can go snap, crackle, and pop

Buttressing tall buildings, reinforcing ships' hulls, keeping keen a razor's edge, steel permeates modern life.

Yet steel has a defect: Under some conditions, it can become brittle and shatter — especially when subjected to extreme cold or strength-enhancing processes.

To understand better why steel may snap, physicists Ruqian Wu and Arthur J. Freeman and materials scientist Gregory B. Olson, all at Northwestern University in Evanston, Ill., used quantum-mechanical methods and supercomputers to analyze how steel fractures.

In the July 15 SCIENCE, they report modeling the effects of two impurities, phosphorus and boron, on steel's atomic integrity. Calculating the energy of the bonds between the impurities and iron,



Wu et al./SCIENCE

Iron atoms with impurities (I) at a grain boundary (A) and a free surface (B).

steel's primary component, the scientists were able to clarify the destabilizing effects of the impurities on steel's "crystal grain boundaries." In doing so, the researchers have helped to explain the mechanisms that give rise to "impurity-induced embrittlement."

"We are looking to design new steels from the ground up," says Olson. "Now we have a clear understanding of the mechanisms of embrittlement, so we can design new steels that minimize the brittle effects. Most of the time when steel fails, it's due to trace amounts of phosphorous" between iron atoms.

"Their work is the most rigorous to date," says Mark Eberhart, a materials scientist at the Colorado School of Mines in Golden. "Many people have speculated on models, but this group's computations agree with the most widely accepted model of embrittlement."

Their calculations, which are very hard to do, have advanced the art of steel making by showing that it's possible to use quantum-mechanical methods" to improve steel.

Shatter-prone steel can pose a hazard, says Eberhart. For instance, during frigid winters, girders exposed to the elements can crack — a problem noted during construction of the Alaska pipeline. And during earthquakes, such fragile supports fail more quickly.

"This work may lead directly to better, less brittle steel, which would be a significant accomplishment," says Eberhart. "This step is within reach." *— R. Lipkin*

U.S. adults: A weighty lot

In the past decade, surrounded by an abundance of low-fat foods, high-tech gyms, and high-fashion sportswear, Americans got fatter. A lot fatter, researchers report.

According to a series of studies, the proportion of overweight U.S. adults age 20 to 74 remained at about 25 percent from the 1960s through the 1980s. But that figure jumped to 33 percent by the beginning of the 1990s, according to the National Health and Nutrition Examination Survey III, in which investigators weighed and measured 8,260 volunteers from 1988 to 1991. Moreover, the average weight of U.S. adults has increased by a hefty 8 pounds, the scientists announced in the July 20 JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION.

"What is surprising is the magnitude of the increase in a relatively short period of time," says report coauthor Robert J. Kuczmarski of the National Center for Health Statistics in Hyattsville, Md. Kuczmarski and his colleagues collected additional data that they are still analyzing on behavior and other variables. These may help explain why so many U.S. adults fail to maintain a healthy weight.

To determine if someone weighed too much, the researchers calculated "body mass index" (BMI): body weight divided by the square of the height. When using kilograms and meters, a BMI over about 27 qualifies people as overweight. It also puts them about 20 to 24 percent above their desirable weight, as listed on a 1983 height and weight table developed by Metropolitan Life Insurance.

Weight varies according to age, ethnic group, and gender, the researchers find. For example, more non-Hispanic black and Mexican American women than men are overweight. Nearly half of these women carry extra pounds, compared to about one-third of the men. Slightly less than a third of non-Hispanic white women and men tipped the scales over a healthy weight.

Only non-Hispanic black men were not apt to get heavier as they aged, Kuczmarski's team reports. *— T. Adler*

Scratching a polymer to guide light waves

As a key component of digital wristwatches, calculators, and portable computers, liquid-crystal displays have become a familiar sight. Consisting of a thin film of milky fluid sandwiched between a pair of polymer-coated glass plates, such devices respond to electrical signals. These control signals shift the orientation of liquid-crystal molecules in selected regions to alter the film's optical characteristics and create patterns of light and dark on the display.

Now, researchers have developed a technique for altering the optical characteristics of liquid-crystal displays to enable them to channel light. They use the needlelike tip of a scanning force microscope to gouge out sets of tiny grooves on nylon-coated glass plates. These grooves, in turn, align liquid-crystal molecules in a specified direction between the plates.

Martin Rüetschi of the University of Basel in Switzerland and his coworkers describe their method in the July 22 SCIENCE.

"We expect that this technique of writing an orientation pattern with a tip of [a scanning force microscope] will trigger the development of new devices," the researchers say. Such devices may eventually play an important role in the development of optical computers and other equipment for processing optical signals.

Liquid crystals are generally made up of large, mobile, rodlike molecules that tend to organize themselves into a lattice. To orient these molecules in a particular direction, manufacturers of liquid-crystal displays typically rub the glass-mounted polymer layers that go into their devices with velvet rollers. The rubbing direction determines the initial alignment of the molecules.

The Basel group found that the tip of a scanning force microscope dragged across a polymer surface makes parallel grooves very similar to those created by rubbing. But the researchers could control the width, depth, and spacing of the grooves and the position and size of the resulting patterns far more precisely than they could just by rubbing the polymer layer.

This enabled the researchers to investigate systematically how the characteristics of the grooves influence the polymer layer's ability to orient liquid-crystal molecules and, hence, the film's optical properties. By selecting a suitable pattern of grooves, they could align liquid-crystal molecules in just the right way for the liquid-crystal layer to act as a waveguide for laser light. This prototype waveguide, 6 micrometers wide and 5 millimeters long, behaves much like an optical fiber and readily channels a laser beam. *— I. Peterson*