of chlorophyll's programmed suicide. In the world's oceans, nature condemns chlorophyll in single-celled marine phytoplankton to a half-life as short as 48 hours. (A half-life is the time it takes for half of the substance to be transformed or degraded.) Overall, the world stock of chlorophyll is close to 250 million tons, and it is turned over 3.7 times each year.

There are several reasons why nature allows this seemingly senseless slaughter. But an important reason has to do with the process of photosynthesis.

As Hendry explains, the chlorophyll molecule can be thought of chiefly as a provider of electrons. Each molecule is surrounded by a cloud of orbiting electrons; when struck by sunlight, the molecule resonates and one of the electrons is flipped out of orbit "along an electrical circuit to drive the production of storable chemical power." Occasionally, however, there is a malfunction, and the electron escapes and attaches itself to an oxygen molecule. The result is an "oxygen radical," one of which, the hydroxyl radical (HO), is a kind of terrorist of the natural world. It "almost instantly abstracts hydrogen from any convenient neighboring molecule, thereby destroying the structure of many organic molecules."

Even animals can be affected. In a rare disorder among sheep called geldikkop, partly digested chlorophyll passes into the bloodstream; sunlight striking the skin causes the chlorophyll to produce oxygen radicals, and the animal to suffer lesions.

Normal malfunctions of photosynthesis are policed by the plant's antioxidants—such as ascorbic acid (vitamin C) and tocopherols (vitamin E)—which also happen to be beneficial to humans. But drought or cold weather triggers malfunctions on a huge scale. As autumn nears in New England, then, nature orchestrates the mass suicide of chlorophyll to prevent an invasion of oxygen radicals, which would disrupt the all-important process of salvaging carbohydrates, proteins, and other useful compounds from the plants' leaves.

This elaborate fail-safe device, Hendry says, allows nature's leafy "solar panels" to operate "with an efficiency and safety record unmatched by anything humans have yet devised."

Big Business, Big Science

"The Scientific Tradition in American Industrial Research" by John Kenly Smith, Jr., in *Technology and Culture* (Jan. 1990), National Museum of American History, Room 5030, Smithsonian Inst., Washington, D.C. 20560.

The brash young pioneers of California's Silicon Valley have revived the dream of the swashbuckling American inventor, freed at last from the shackles of big business. There is indeed something new happening in the relationship between science and business, writes Smith, a historian at Lehigh University, but Silicon Valley exemplifies the past, not the future.

That relationship began during the 1870s and blossomed into marriage because of new competitive pressures on big business generated by the expiration of many old patents and by the federal government's vigorous antitrust efforts. By World War I, the pioneers of U.S. industrial research—General Electric, DuPont, AT&T, and Kodak—had all established their own laboratories to help them maintain market share.

At first, Smith says, "American industries cast a wide net for new technologies but in general did not expect to invent them. Rather, they made use of the work of independent inventors." That strategy was a success, producing such technological and marketplace triumphs as cellophane (DuPont), refrigerators (GE), and color film (Kodak).

By the 1930s, however, several corporate laboratories were beginning to change: "Instead of just applying science, industrial researchers would 'do' science," Smith notes. This kind of basic research led to the creation of nylon at DuPont in 1934 and of the transistor at AT&T in

1947. After World War II, presidential science adviser Vannevar Bush and other leaders persuaded corporate executives that "basic science led directly and rather quickly to new technology," inaugurating a new era of basic research. Corporate laboratories completed the change toward academic-style research; the laboratories themselves were frequently relocated in suburban office parks, literally and symbolically far from the plant and corporate headquarters.

As early as the 1950s, however, corporate managers began to sour on the "ivory tower" approach. Where was the new nylon or the new transistor?

Today, says Smith, the search is on for a new model. He doubts that a return to the days of the heroic individual inventor is possible. The upstart Silicon Valley firms that have revived these hopes relied on two big institutions: from the Pentagon came research money and from AT&T's once-famed Bell Labs came technology and personnel. But American corporate laboratories no longer seem to have the knack for good applied science, either. So what will the next phase of the business-science marriage be? Perhaps the partners may try living apart, Smith suggests. A portent may be GE's sale last year of the RCA research laboratory to the RAND Corporation, thus creating a huge independent research establishment.

RESOURCES & ENVIRONMENT

Pedal Power

"Reinventing the Wheels" by Marcia D. Lowe, in *Technology Review* (May–June 1990), Building W59, MIT, Cambridge, Mass. 02139.

Maybe all those cab-dodging downtown bicycle couriers know something. Traffic jams and air pollution, not to mention the shortage of decent radio stations, make driving a car in the city a hellish experience. Buses and subways are often crowded and slow. So the urban messengers—along with some gridlocked policemen in London and Los Angeles—have turned to the bicycle.

America's first bicycle craze began in 1876. In 1884, a California man even set off to cycle around the world; it took nearly three years. Here, cyclists take a break near Tallahassee, Florida.

The humble bicycle, insists Lowe, a Worldwatch Institute researcher, is a kinder, gentler form of transportation that ought to figure prominently in the nation's transportation plans. "All you have to do," one California town official told her, "is make it easier to ride a bike than drive a car. People will take it from there."

Over hill and dale? Through rain, sleet, and snow? Lowe does not say. But a few pro-cycle societies have taken some bold steps: Bicycle parking towers dot the cities of Japan; Swiss buses are