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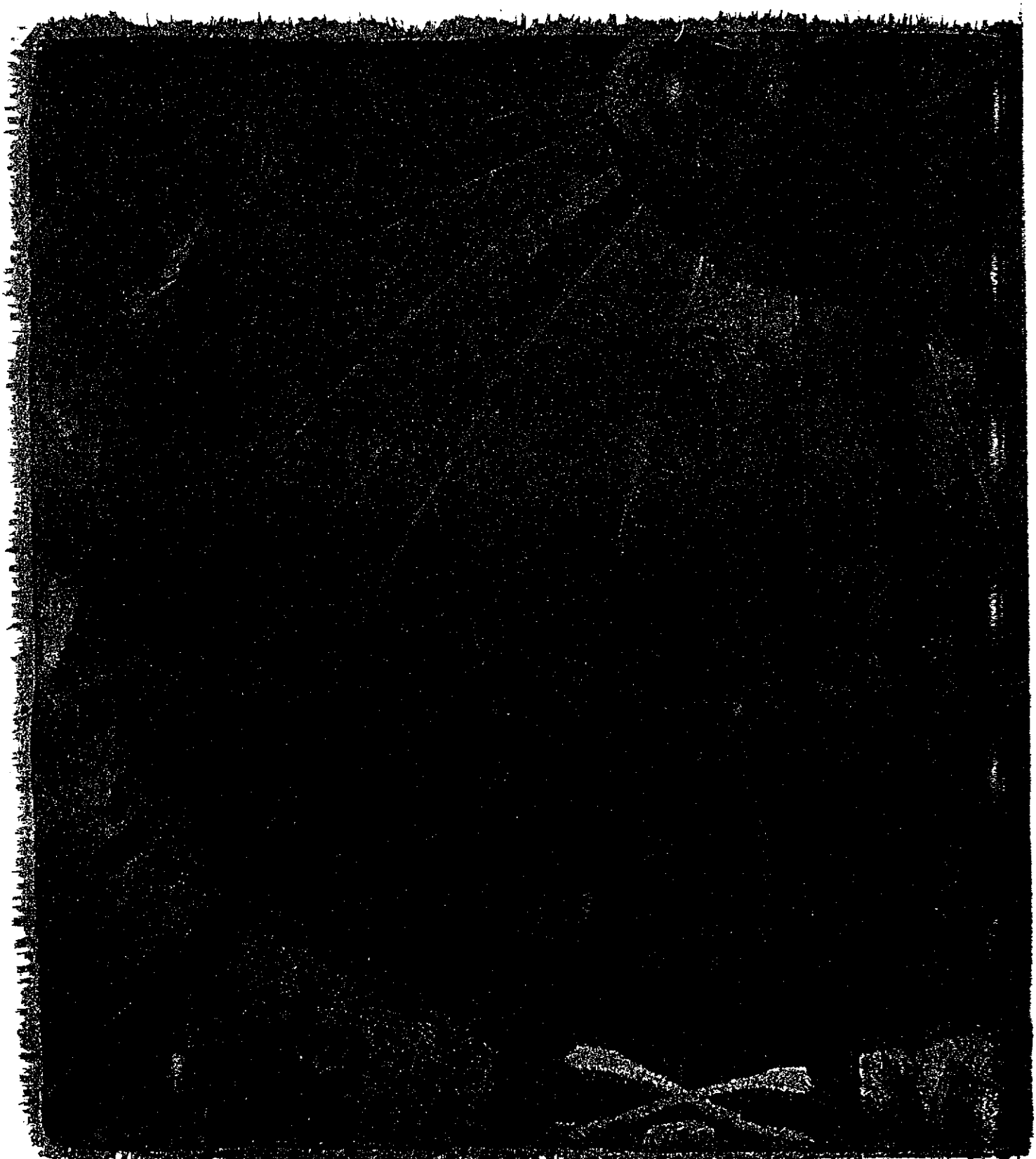
By John F. Ross

RISK: Where do real dangers lie?

The first of a two-part series



We have always had to assess the chances that bad things will happen; now, new tools give us hard numbers but also raise new questions

The aftermath of the earthquake is frightening: fanned by strong winds from the west, fire races across the city of San Francisco. I can't help but hold my breath as I witness this Armageddon.

I look up from the computer monitor and stare outside. It's rainy but otherwise an ordinary day in the Bay Area. On the screen the simulation continues, the computer counting the minutes as fire engines, represented by flashing blips, move along a gridwork of streets to battle the inferno. Hemant Shah of Risk Management Solutions has re-created the conditions of the 1906 San Francisco earthquake and overlaid it onto today's city. The company performs this simulation to anticipate what might happen in the event of a quake. Factored into this model are countless specifics that only a computer could juggle: the location of gas mains, the kinds of firebreaks, the speed of fire engines battling rubble in the roadways, the type of construction of various buildings, as well as soil types and ground conditions.

Seven hours later, when the fires have burned out or been controlled, a series of blimp- and cigar-shaped splotches mar the city grid; they indicate fire damage. With this information, Shah can calculate the claim costs for an insurance company.

The insurance industry has been burned recently by earthquakes, hurricanes and tornadoes. Florida's Hurricane Andrew alone bankrupted nine insurance companies. Itchy to know their vulnerability to natural hazards and their "probability of ruin," insurance companies have lined up for the help of Risk Management Solutions. Shah's company is on the leading edge of the new science of risk theory: how we recognize, understand and manage the hazards that surround us. On Capitol Hill last summer, the House passed legislation requiring both risk assessment and cost-benefit analysis before any new federal regulations are imposed. A similar bill stalled in the Senate. It appears that "risk analysis," "risk management" and "risk communication" will become trendy phrases on the lips of politicians, health experts and environmentalists.

We've always been concerned with risk, defined as the probability that something harmful will occur. Yet the past 15 years have brought an explosion of interest, as computers, statistical databases and highly sensitive quantitative techniques bring new tools to the task of assigning hard numbers to probabilities that range from the personal and mundane to the global and catastrophic. How we interpret and use these numbers is influencing how we live our lives, as well as how our society allocates limited resources. The numbers can embolden us

The game of risk is not unlike roulette: making the right decisions is akin to choosing the right numbers.

Illustrations by Kate Mueller

to feel that we are masters of the Universe. Or they can make us feel despondent under the burden of making correct decisions. The subtleties of the questions ripple through the fabric of our society and threaten to recast the way we view the world.

Each of us makes hundreds, if not thousands, of risk assessments every day. How fast will we drive if we're late for an appointment? Is speeding, with its risk of a ticket and increased chances of an accident, worthwhile if the meeting is important? Is a healthful lunch worth an extra expense? Should you place your retirement portfolio in stocks, a more risky path than some other investments but one more likely to keep pace with inflation over the long run? Lately it seems that understanding the risks in our daily lives has become a full-time job as we're bombarded constantly with warnings and new findings.

At a toxic waste site, should cleanup continue until a child can safely eat dirt there each day for 250 days?

If we want to stay healthy, we must become risk experts ourselves and sort through the overwhelming and often complex information swirling around us like a dust cloud. Much of the material is contradictory: read periodic press reports about caffeine and you'll never know whether or not it's OK to drink coffee. Based on observations made a decade ago on the Greenland Inuit diet, we've learned to eat fish more often. Now a new study from the Harvard School of Public Health finds that eating fish does not make any difference in the rate of heart disease among men. Reports conflict on whether we should have an occasional glass of wine for good health or steer clear of it to avoid breast cancer; on whether we should spread butter with its saturated fats or margarine with its trans fatty acids; on whether we should take an aspirin a day to keep the doctor away or avoid it altogether for fear of bleeding ulcers and other side effects.

Then there's the whole category of possible risks on which the scientific community remains divided. Take radon, for example. This is an odorless, radioactive gas that seeps from the ground into many basements. It could be one of our chief environmental health risks, with 1 in every 15 homes estimated to have elevated radon levels. Worse, it could be causing anywhere from 7,000 to 30,000 lung cancer deaths a year. Yet some scientists are suggesting that radon is not a significant health risk. In some cases, science just can't give us a definitive answer. The fear of litigation adds even more confusion to the picture as manufacturers and employers issue absurd warnings to protect themselves.

Infectious organisms in your pocket

While confusion reigns in some areas, solid numbers are being nailed down in others, data unequivocal enough to change the ways all of us think about risks. Did you know, for example, that in this country about one person a year dies from ingesting a toothpick? This minuscule death rate is actually higher than that attributed to widely feared asbestos. Did you know that more people die using crosswalks than while jaywalking? (Most people use the crosswalks, and jaywalkers tend to be more alert.) Do you worry about picking up a germ while visiting a friend in the hospital? You're more likely to acquire germs from the money in your pocket right now. One out of every ten coins and almost half the paper currency carry infectious organisms.

Risk itself has always been a part of our landscape; responses to some risks are hard-wired into our beings in the form of instinct. A finely tuned recognition of immediate risks to our body is a prerequisite for survival. No risk will ever be clearer than a saber-toothed tiger stalking one of our ancestors. More complex risk assessments, however, require calculating the ratio of costs to

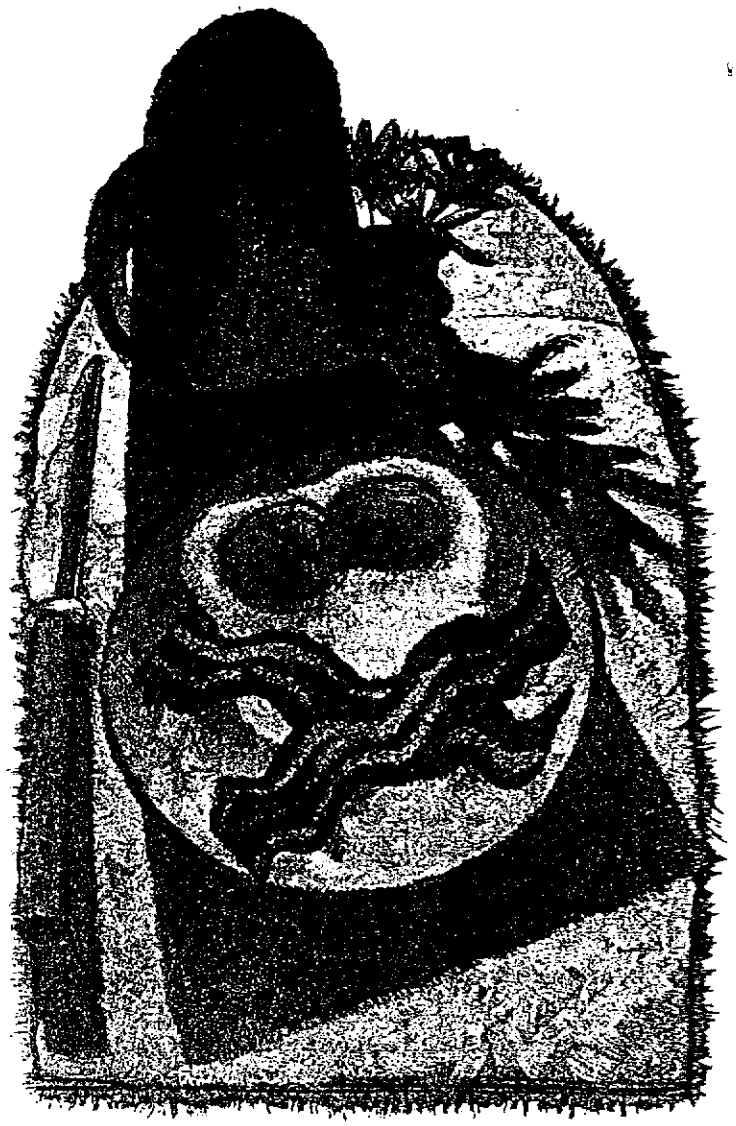
benefits, rather than just responding to a hazard. When Cro-Magnon man, armed only with a spear and his cunning, decided to hunt a mastodon the size of a small house, he knew that he stood great risk, but the potential gain (enough meat to feed his family for a long time) was also great. Modern risk theory would probably suggest that he chase rabbits year-round instead.

In our complex and technological society, threats to our person are usually less immediate. In some cases, technological advances have turned once life-furthering biological imperatives into life-threatening ones. Our bodies, for instance, crave fat, a way of storing energy for times when resources are scarce. Today in the industrialized West we can eat as much fat as we like, but that desire is making us ill with heart disease, obesity and a host of other problems.

How much are we willing to pay?

While risks abound, the good news is that Homo sapiens has been particularly ingenious at inventing ways to minimize risk. In the parlance of risk theorists, this approach is called risk management. Thus, as I slip into my car for a short trip to the drugstore to pick up antibiotics for my son, a warning beeps if I don't don my seat belt and, down the road, guardrails prevent me from skidding off an embankment. Undoubtedly, driving will be the most hazardous aspect of my day (110 Americans die in car accidents daily). On the radio I hear that some stocks I've bought are down, but I'm not overly concerned because they're among hundreds of others in a mutual fund that spreads the risk. When I pick up my son's medicine, I fumble with the childproof cap, an ingenious risk-management device. The downside of the antibiotics and these other risk-management tools is that they cost money. They are a choice: the money spent to buy antibiotics is no longer available to buy something else. Similarly, billions spent to clean up Superfund sites are not available to, say, immunize children. Yet most of us agree that these particular strategies are well worth the price. But how far will we go, or how much are we willing to pay, to minimize other risks where the payoffs are less clear-cut? That's where risk theory gets interesting.

The discipline of risk assessment has come from the melding of several different areas of study. Any meeting of risk experts today will probably include engineers, safety experts, physiologists, policy analysts, psychologists, toxicologists and statisticians. An early form of the science came with the discovery of radioactivity at the turn of the century, prompting biologists and health physicists to examine the health impact of exposure to the curious new phenomenon. Later, studies of the survivors of Hiroshima and Nagasaki provided information on the effects of severe doses of radiation. Engineers



Is a healthful breakfast hazardous to your health? At times it seems as if everything we eat is bad for us.

also contributed fundamental information for risk analysis as they pored over the safety of nuclear power plants, dams, chemical plants and other large civil projects. They designed models and contingencies based on the probabilities of certain failures—and strings of failures—occurring. Their pioneering work in "what if" modeling is still used today.

Another building block of risk assessment was the compilation of fatality statistics for automobiles and airplanes that began in the 1930s. In 1975 the National Highway Traffic Safety Administration set up a computerized data file called the Fatal Accident Reporting System. It now contains information about the more than 800,000 highway deaths that have occurred since then, recording details that range from the speed and make of the vehicle to the time of day and the age and sex of those involved. Using these results, traffic safety scientists have been able to characterize the risks of driving. While common sense dictates that a larger car is safer to

drive, the numbers tell us how much: overall, you are 17 times more likely to die in a head-on crash if you're driving a small vehicle. Wearing seat belts reduces the chance of the driver's dying in an accident by 42 percent.

Large epidemiological studies over time have revealed links between certain activities and higher mortality—smoking cigarettes, for instance, is a big one. Again, while we could intuit that smoking was not great for our health, the crunching of large numbers began to show clear and certain correlations—and was the genesis of the Surgeon General's ubiquitous warning label. Squeezing the numbers further, some scientists now say that, statistically, one cigarette cuts five minutes off your life span. Other numbers are even more disturbing. For example, unemployment beats out steeplejacking as the riskiest "occupation." So heightened is your risk of suicide, liver cirrhosis from drinking alcoholic beverages, and other stress-related diseases while not working, that being unemployed rates as the equivalent of smoking ten packs of cigarettes a day. Being poor is equally dangerous. Living in poverty reduces your life expectancy by about nine years. But there's good news as well as bad. If you're a man, think about getting married: the averages suggest that you will outlive your bachelor friends by five years.

Feeding megadoses to white rats

While epidemiologists were making these correlations, toxicologists were testing carcinogens on living creatures. Laboratory animals that were fed huge quantities of certain chemical compounds would develop tumors. This result was extrapolated to humans—though the debate about the applicability of these tests to humans still runs hot. As a result, in 1958 Congress devised the Delaney Clause, which forbade the use of any chemical in processed foods that produces tumors in laboratory animals at any dose.

Before the 1970s, risk from contaminants was a pretty much black-and-white issue. Scientists simply looked at whether the pesticide DDT, for instance, was carcinogenic (cancer causing) or mutagenic (gene mutating). Back then, only a handful of chemicals appeared to cause cancer. Today, two-thirds of the more than 800 chemicals tested so far have been found to cause or promote tumors in rodents. Yet more than 50,000 synthetic chemicals remain untested. Now we also know that carcinogens differ enormously in potency, so it's no longer a matter of either/or but also of how much.

Complicating the science of cause and effect are our great leaps in quantitative chemical analysis. In the 1950s, scientists measured things in parts per million. Today, with modern equipment, scientists can measure amounts down to parts per trillion (1,000,000,000,000). Thus you could have a situation where a processed food was found to contain one part per trillion of a compound known to cause tumors in rats when administered in massive doses. Under the Delaney Clause, that food could not be sold, even though no one can show that having the contaminant present at such a low level could cause cancer in humans.

Each of us walks a tightrope. Diseases, accidents, toxins: any of these could plunge us into an abyss.

All of life is a risk. Take a deep breath and hold it. You've probably inhaled molecules of Earth's deadliest toxins: dioxin, radon, benzene, formaldehyde. How do we understand the effect of something so small on the human body, and should we be concerned? At what point do real risks begin and others remain negligible? Certainly the Delaney Clause of 1958, with its zero-risk intentions, is hopelessly out of date with what we know

Although he knows the odds are heavily against him, John F. Ross occasionally plays the lottery. He is a freelance writer, living in Bethesda, Maryland.

But the pink slip is a menace too—for the stress of unemployment is among the greatest dangers of all.

today. Yet before Congress sweeps it into the dustbin, new guidelines on food safety will have to be thrashed out, which will be no easy task.

The numbers themselves present another problem because most of us (myself included) find it hard to visualize anything larger than 1,000 units of anything. In our largely innumerate society, risks expressed as 1:10,000 or 1:1,000,000 seem little different. Risk communication, the third branch of risk science, addresses the need to put these numbers into context; it is about how you and I understand risk in our lives. And we don't always do a very good job.

In a landmark test in 1980, a group of psychologists asked a representative sampling of the populace to rank 30 activities and technologies by risk; then they compared the results with rankings assigned by a panel of risk-assessment experts. In places, the two groups agreed, such as on the risk of motor vehicles, placed number one by the experts and number two by the public. But on others, there were large discrepancies: the public rated nuclear power as their number one risk, whereas the experts ranked it as a lowly number 20. Experts ranked x rays as number 7, while the man-in-the-street saw them as number 22. What, the risk-communication scientists next asked, was influencing the public's perception of risk?

For starters, they found that the public responds differently to voluntary and involuntary risks. You and I are willing to tolerate far greater risks when it is our own doing, such as smoking cigarettes or climbing mountains. But if the risk is something we can't control, such as pesticides on food or radiation from a nuclear power plant, we protest, even if the threat is minimal.

We remember only spectacular deaths

Second, we tend to overestimate the probability of splashy and dreadful deaths and underestimate common but far more deadly risks. Many people can remember nearly every case of botulism in the United States because the incidence of it is so small and the press coverage so large. This results in a perception that the risk is higher than it really is. Along with botulism, people tend to overestimate the risk of death by, say, tornado. On the other hand, stroke and heart attack, which have affected all of our lives in some form, don't seem as dreadful, probably because they are so common. The general public ranks accident and disease on an equal footing, although disease takes about 15 times more lives. Although 40,000 people die on American highways each year, and another 400,000 from smoking-related diseases, a single crash of a jetliner with 300 people aboard draws far more attention from the press. Spectacular deaths make the front page; ordinary deaths wind up back on the obituary page.

Yet another factor about how we rank risks revolves around whether or not the risk is perceived as "natural." Although I am generally good about applying sunscreen, sometimes I forget and I'll get a burn. What seems more natural than an outdoor activity on a nice sunny day? Yet it involves serious risk: skin cancer, for starters. The National Cancer Institute has computed that one serious sunburn can increase your risk of skin cancer by as much as 50 percent. Over a lifetime, one out of every seven people in the United States could develop melanoma or other skin cancer from overexposure to the sun. Yet people often remain lackadaisical about applying protective lotion. Because the sun is "natural," it doesn't carry the specter of death associated with the asbestos used in insulation. Asbestos poisoning, however, is an insignificant threat to Americans when compared with cancer caused by sun worship.

Perhaps the most dramatic example of erroneous

public perception of unnatural and involuntary risk occurred in 1989 when CBS News' *60 Minutes* ran a show alleging that the chemical daminozide—under the trade name Alar—put children at great risk for cancer. Used by a small percentage of the nation's apple growers in the 1980s, mostly on red delicious apples, Alar is a growth-regulating chemical that is applied to keep apples from falling off the tree too early. Backed by a large apple and a skull and crossbones, anchorman Ed Bradley reported that Alar was the "most potent cancer-causing agent in the food supply today." In 24 hours, the country erupted in fear and panic. A woman called the Environmental Protection Agency and asked if she could pour her apple juice down the drain or whether she should take it to a toxic waste dump. School districts in Los Angeles, New York and other cities immediately banned apples and apple products from their cafeterias, and many millions of dollars' worth of apples were dumped into ditches. Actress Meryl Streep, a concerned mother, joined the fracas: in a TV commercial she used a detergent to wash pesticides off vegetables. The public appeared to believe that one bite of an apple treated with Alar could strike you dead. The apple industry lost more than $100 million, and a number of small-scale growers, many of whom had never even used Alar, went out of business.

Asbestos in classrooms may be a hazard to children, but greater dangers may lurk outside of school.

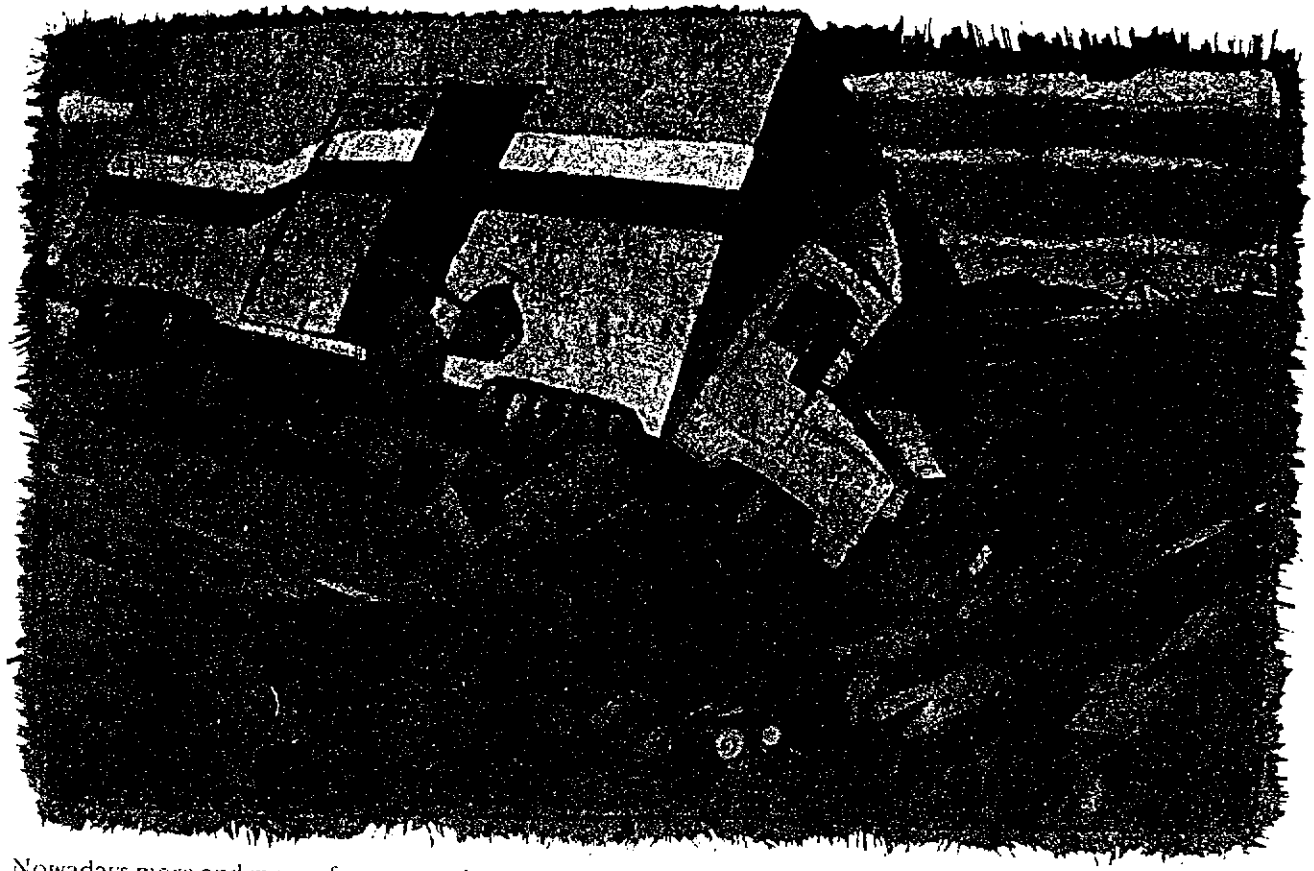
The panic originated from a controversial report of questionable science in which laboratory mice developed tumors when exposed to 35,000 times the amount of Alar that children were normally exposed to. Uniroyal, the maker of Alar, took it off the market. Later, several independent reviews found the threat minuscule, but by that time the notion of "deadly Alar" was firmly entrenched in the public's mind, and it remains off the market today.

Bruce Ames, an outspoken molecular biologist at the University of California at Berkeley, dismisses the Alar episode as a purely emotional reaction by a news media and public not fluent with relative risks. His research suggests that the human role in putting carcinogens into the food supply—in the form of pesticide residues—is minimal compared with what nature does. Over time, all plants have evolved sophisticated biochemical defenses against their enemies: fungi and herbivores. Lettuce, celery and beets contain caffeic acid; peanuts, corn and milk can contain mold toxins, such as deadly aflatoxin and sterigmatocystin; eggs contain benzene. Even the process of cooking food produces carcinogens. These naturally occurring chemicals are as carcinogenic as any synthesized by chemists. After Ames added up all the naturally occurring chemicals in a regular diet, he found we eat 10,000 times more natural than man-made pesticides.

Those carcinogens in your coffee

Coffee, Ames says, is not dangerous, but it contains 1,000 natural chemicals, and only 26 have been tested. Of these, 19 have produced cancer in laboratory animals. Under the current law, if coffee were synthetic, the FDA would ban it. Yet the cancer risk of an apple with Alar residue is far less than the risk from the natural compounds in a cup of coffee. Ames throws the pesticide controversy on its head by suggesting that pesticides actually decrease our incidence of cancer. Pesticides reduce production costs, thus making fruits and vegetables cheaper. So, he concludes, more people will eat more fruits and vegetables—a proven strategy for significantly reducing cancer and heart disease.

Cancer is the risk people worry about more than any other. In 1981 Congress' Office of Technology Assess-



Nowadays more and more of us are moving to the areas that are most threatened by natural hazards—earthquakes in California, tornadoes in Texas, and frequent hurricanes in Florida and up the East Coast.

ment commissioned two Oxford epidemiologists, Richard Doll and Richard Peto, to examine the roots of cancer in this country. (Doll and Peto are the scientists who perfected the technique of meta-analysis: looking at all the studies done on a subject in a statistically weighted way so that more information, and more certainty, can be extracted than from any of the individual studies.) They found that roughly one-third of the cancers were caused by smoking and smoking-related behavior, another third by diet, and the remainder mostly by lifestyle choices, such as occupational and recreational activities. Environmental carcinogens accounted for only 2 percent of all cancers, they wrote.

Such results have been music to the ears of those opposed to government regulation and have made risk analysis less than popular with many environmental groups. As the Environmental Protection Agency can attest, however, the health of human beings is not the only reason to try to protect the environment. Threats to other species, to ecosystems, even to the entire planet must enter the equation. More than any other governmental agency, the EPA has furthered the science of risk analysis, which has become one of the agency's best tools in supporting its mission to evaluate the health of the environment and regulate threats to it.

In 1987 the EPA did a study titled "Unfinished Business." The agency found that it was spending vast sums of taxpayer money on certain activities that were inconsequential to the number of lives saved and the overall environmental impact. A prime example is the Superfund, the pot of money designated for cleaning up toxic waste dumps. Everybody agrees that toxic waste dumps do not represent our finest hour. But should we spend billions of dollars to clean them up to the last speck? How did the EPA define the group at risk if the cleanup were to be less than total? Very conservatively. Suppose, for example, that some pollutant has accumulated in the bottom of a pond. How much cleanup should the EPA require? Not down to the last molecule, the answer comes, but enough, in some cases, so that a child could eat bits of that mud for 250 days a year without becoming seriously ill. Our emotional reaction to and abhorrence of toxic waste dumps have spurred us into remarkable action. We're spending $6.1 billion a year on hazardous waste to prevent as few as 500 cancer deaths a year. Compare that with the $100 million-plus spent on reducing

For a while we regarded apples as bombs waiting to explode, but finally the Alar scare fizzled out.

the risk of lead poisoning for millions of our children.

In 1992 the U.S. Government incorporated risk assessment into its budget considerations and brought more cost comparisons to the table. It noted that the EPA's regulations ranged from spending $100,000 per premature death prevented (by mandating certain car-safety standards) to as much as $5 trillion (by designating and then regulating wood-preserving chemicals as hazardous waste). Numbers like that last one have led certain scientists to contend that some government programs are the equivalent of "statistical murder" because they take limited resources and devote them to mitigating negligible risks. Any such numbers raise a core question that no one wants to answer. How much is a human life really worth? Is a younger person worth more than an older person? Is it better to save one life or help 10,000 people who are sick all the time? Technology has pushed us into an ethical corner before we've developed the means to find our way out. Risk theory can only sharpen the questions; it cannot by itself solve the ethical dilemmas.

We're also realizing that the trade-offs are not always so clear. Reducing risk in one area may very well increase the risk in another. John Graham at Harvard University uses the example of the fuel efficiency of cars. Most people would agree, he suggests, that higher fuel efficiency in automobiles is a positive goal, representing less air pollution and dependence on foreign oil. If, however, the government pushed up the average miles-per-gallon requirement for new cars from 27 miles per gallon to 40, manufacturers might be forced to make smaller and lighter cars. Graham calculates that these less-safe cars would eliminate the entire safety gains realized from air-bag technology. Is less air pollution worth more fatal accidents? Or take the very costly removal of asbestos from the New York City schools. Some have suggested that the weeks the children spent out of school were far riskier to their health than the actual asbestos itself.

The questions become even more interesting when applied to more-hypothetical risks, the ones with small likelihood but huge impact. Last year, two scientists analyzed in great detail the risk of a large asteroid or comet's hitting Earth in the next century. We're hit often enough by small extraterrestrial debris or meteorites. But there is strong evidence of impacts by larger bodies, the most famous being one that scientists believe occurred on the Yucatán Peninsula 65 million years ago. The dust sent into the atmosphere catastrophically affected Earth's environment and may have led to the extinction of the dinosaurs. Although the chance that it will happen is slim, the consequences of such an impact if it does happen are extraordinarily great. The two scientists calculated that if you live for the next 65 years, you have a 1-in-20,000 chance of dying from an asteroid or comet impact. Compare this with the risk of being killed in events that are far more common but have only local impact: a flood, 1:30,000; a tornado, 1:60,000. To put this in perspective, the chance of being dealt four aces in a hand of five-card stud is 1:50,000.

Should we then develop costly programs to divert an incoming asteroid or meteor with nuclear bomb blasts? Can we afford to, when people on Earth are still dying from more immediate and preventable risks, such as malnutrition and infectious diseases?

Risk Management Solutions' earthquake expert Haresh Shah, who is Hemant Shah's father, suggests that we mostly tend to ignore these large-impact, low-probability risks. Urbanization and growing populations, he believes, are putting people increasingly at risk from natural disasters. We can assume that earthquakes occur with a relatively constant regularity over geologic time. Today, populated areas near fault lines are becoming more and more densely packed at an ever increasing pace. When the 1906 earthquake hit San Francisco, about a half-million people lived in the area. Should a quake of the same size strike today, six million people would be at risk. By the year 2000, more people will live in urban areas than there were people on the entire planet just 50 years ago.

Also by 2000, about 75 percent of all people will live within ten miles of a seacoast, an area often at greater risk from earthquakes and hurricanes.

In the crowded cities, the construction of buildings now proceeds on formerly undesirable locations: reclaimed waterfront land and steep hillsides. Thus when an earthquake hits, many more people are at risk. During Japan's great Hanshin earthquake in January 1995, buildings on two artificial islands in Kobe Harbor were among the hardest hit. In the United States, the top relocation areas are plagued by natural disasters: Florida, hurricanes; California, earthquakes; Texas, tornadoes and hurricanes. Technology is not advancing quickly enough to protect the fast-growing concentrations of people and their attendant economies. While technology will help us chip away at the total percentage of fatalities in natural disasters, the growing numbers of people in high-risk areas will result in larger actual numbers of deaths.

One question remains. Are we safer than we were, say, 100 years ago? A single number gives us that answer. Our life expectancy was 47.3 years at the turn of the century and has climbed to 75.8 years today; it continues to grow. In the past ten years, life expectancy in the United States rose 1.4 years, thanks to better medications, better diets and better risk management in our personal as well as our collective lives. In fact, the cancer we see around us is actually a sign of how well we're doing. Not too long ago, most people didn't live to middle age and rarely got cancer because other, more immediate causes got them first.

Does all this mean you should have an extra pat of butter on your blueberry muffin tomorrow morning? Probably not; you've got to watch your cholesterol, you know. But does it mean you should lose sleep about being bonked on the head by a meteorite? Don't worry, you have a better chance of winning the lottery.

Next month: How does the human body cope with risk?

We are not always good at putting the numbers into context. Some risks we perceive as higher than they really are. Are we then turning our backs on a raging inferno while we douse the flame of a match?