phisms. He has several possibilities, but they are still very embryonic. Meanwhile he has found two more polymorphisms: "These are base-pair polymorphisms," he says, "and they are not as variant as the first one. We expect to find some of these, but the ones we're really interested in are those resulting from a range of transposable genetic elements."

White points out that much of the 9 months devoted to the discovery of the first polymorphism was concerned with the development of techniques. Nevertheless, it's clear that a considerable effort would have to be directed to the task of filling the required list of markers, even if new and faster techniques are forthcoming.

Victor McKusick's compendium of genetic diseases—*Mendelian Inheritance in Man*—lists all that is known for several thousand inherited conditions. "For the most part the data on these diseases are terrible," says Botstein, "and that's because they are so difficult to obtain." The system being nurtured at MIT and Utah offers the possibility of a real improvement here, mostly by circumventing the type of information classically required by geneticists.

Although Botstein acknowledges the potential of the work, he insists that "there is still a very long way to go, and there has to be a chance that it will turn out to be impractical." White's commitment to the work is demonstrated, he says, "by the fact that I've voted with my feet." He is fully optimistic about the final outcome, and comments that the project is "a delightful example of real fallout from basic research."

—ROGER LEWIN

There Is More to "Acid Rain" Than Rain

Significant amounts of acid and other pollutants reach the ground without the aid of precipitation, but most of it goes unrecorded

Scientists are not happy with the term "acid rain." It serves well in newspaper headlines and as a catchword for a growing international pollution problem. But "acid rain" neglects a part of the acid that has left mountain lakes barren of fish and corrodes car finishes. Some of that acid and numerous toxic chemicals, spewed from smokestacks and tail pipes, are being deposited on lakes, streams, trees, and fields without being washed out of the air by rain or snow.

The proportions of dry and wet deposition depend on the distance from the source of pollution and the wetness of the climate, but some scientists estimate that 10 to 30 percent of the acid problem may result from dry deposition. In some places, the figure seems to be at times greater than 50 percent. Researchers also agree that the dry deposition of pollutants, especially acid, is monitored crudely at best. While research on practical monitoring methods slowly progresses, a dispute continues about the usefulness of present methods, which were developed in the 1950's to deal with radioactive fallout.

One problem with measuring dry deposition is that acid, lead, arsenic, cadmium, and other pollutants do not always simply fall out of the sky, like raindrops or motes of dust. If they did, researchers could simply put out a bucket to catch them. Instead, some pollutants form particles so small that they fall slowly or, for all practical purposes, do not fall at all. A 0.1-micrometer particle, which can be formed by the chemical reactions of combustion gases, will be wafted around a flat surface rather than fall on it. Gases that can produce acid when dissolved in water, such as sulfur dioxide, do not fall at all.

Such finely divided particles and gases may not "fall out" onto the landscape, but they still reach the ground without being washed out by precipitation, apparently because natural surfaces can "catch" pollutants that a bucket cannot. In southern Ontario, near the ore smelting industry in Sudbury, conventional collectors miss as much as 60 percent of the sulfate—and presumably much of the sulfuric acid—entering lakes there, according to Peter Dillon of the Ontario Ministry of the Environment in Rexdale. He concludes that not all of the inputs of sulfur have been accounted for because more sulfate flows out of lakes than appears to enter them. Also, too little measured acid enters a watershed to account for the observed chemical compositions of lakes and streams. Much of the missing sulfur must add acid to a lake's watershed, Dillon says, because more calcium, magnesium, sodium, and potassium, which are leached from rocks and soil by acids, leave the lake than could be accounted for by the measured input of acid. The missing sources of sulfate amount to more than 60 percent of the total in watersheds 5 kilometers from the source at Sudbury, 40 percent at 10 kilometers, and 30 percent at 40 kilometers.

Most of the sulfur not collected by samplers as it enters the watersheds seems to be in the form of sulfur dioxide. That gas would not be collected efficiently by the wet deposition sampler—a pot that opens only during precipitation—or by the bulk sampler, a pot that remains open at all times to collect precipitation plus any particles that settle out. Sulfur dioxide would dissolve in the lake and in moisture on vegetation or in the soil, and it can be taken up directly by vegetation. Enough was in the air over the area to account roughly for much of the missing sulfur, Dillon says.

Farther from sulfur sources, the apparent contribution of sulfur dioxide decreases. Dry deposition remains significant, however, because the farther polluted air travels, the more sulfur dioxide gas is chemically transformed into sulfuric acid that forms submicrometer droplets or coats other particles. If not washed out of the atmosphere by precipitation or neutralized by basic substances, these particles can also carry acid to the surface. In the Haliburton-Muskoka area of southern Ontario, 200 kilometers from any large urban or industrial centers, about 20 percent of the acid was collected in bulk samplers, but not in wet-only samplers, according to a report by Wolfgang Scheider, Warren Snyder, and Bev Clark of the Ontario Ministry of the Environment.

Researchers have found that other watersheds having different climates and different sources of pollution also receive significant amounts of pollutants through dry deposition. The Hubbard Brook watershed in northern New Hampshire receives about one-third of its sulfur in a dry form, says Gene Likens of Cornell University. Most of it arrives

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as acid-forming sulfur dioxide, he suspects. In the Adirondack Mountains of upstate New York, where the Integrated Lake Watershed Acidification Study is being conducted, about one-third of the sulfate deposition is also dry, according to Carl Chen of Tetra Tech, Inc., of Lafayette, California.

Although bulk deposition samplers and even entire watersheds have been used to collect dry deposition, no one is particularly satisfied with present estimates of the magnitude of that deposition or current understanding of how it occurs. Watershed studies do not allow the processes involving different types of dry deposition to be separated, and an open pot is not a leaf, piece of bark, blade of grass, or lake, where the actual deposition occurs. The difference is significant. The deposition of a particle may depend on whether the surface is sticky or hard, wet or dry, rough or smooth, featureless or prickly with microscopic hairs, or hot or cold.

Among the first attempts to measure dry deposition using an artificial, or surrogate, surface was one in which researchers studying radioactive fallout set out stainless steel soup bowls. No one thought that they resembled natural surfaces, but the bowls did seem to collect reasonable amounts of fallout. Fancy versions of the original soup pots are now being used by the National Atmospheric Deposition Program (NADP), the largest U.S. deposition monitoring effort, to supplement measurements of acid precipitation. But most researchers, including NADP personnel, do not think they know how the data collected so far should be interpreted. In addition to theoretical questions about how a pot compares to natural vegetation, the contamination problem appears to be extensive, according to Bruce Hicks of Argonne National Laboratory, who is chairman of a NADP technical committee. He found that during the 2-month sampling periods, bird droppings contaminated 50 percent of the sites 50 percent of the time. Other contamination included twigs, insects, and, once, a dead bird.

A recent Environmental Protection Agency workshop report* condemned the use of surrogate surfaces for the measurement of dry deposition; ". . . present capabilities to monitor dry deposition in a practical, yet accurate, manner are inadequate," it concluded. "Techniques to measure, let alone [routinely] monitor, fluxes of species associated with acid deposition are presently deficient." The only point in continuing the use of the NADP dry collectors, it said, might be to determine long-term trends in the deposition of relatively large particles, which are less affected by the nature of the collecting surface.

A minority of those attending the workshop disagreed. The report's summary notes that "20 to 30 percent" of the specialists present "feel that the use of surrogate surfaces should be pursued in some fashion." Like the majority, most of these researchers do not know exactly what to do with NADP's data from the current sampling of dry deposition. They do have some hope of learning enough about how particles and gases are deposited on natural and surrogate surfaces to be able to relate the two. Steven Lindberg of Oak Ridge National Laboratory and Cliff Davidson of Carnegie-Mellon University, who coauthored a dissenting view as an appendix to the workshop report, argue that surrogate surfaces such as Teflon, polyethylene, or filter paper can at times behave somewhat like natural vegetation.

As an example of the possibilities, Lindberg and his group compared the performance of polyethylene petri dishes and chestnut oak leaves. They suspended clean dishes in the upper branches of a tree near leaves that had been cleaned by washing. Analyses of dish and leaf washings a few days later showed that the dishes had collected sulfate, manganese, cadmium, and zinc at the same rate as the leaves, within a factor of 2. The deposition rates for lead differed by a factor of 10, perhaps because of absorption of lead by the leaves, Lindberg says. Lindberg and Davidson believe that such evidence, limited as it may be, should encourage further comparisons of deposition on surrogate and natural surfaces, especially in light of the expected long wait for alternative monitoring methods.

Many researchers do not see much future in that approach or prefer working on alternative techniques that promise more direct measurements of dry deposition. The techniques recommended in the workshop report for continued attention are micrometeorological methods in which small-scale meteorological observations are made along with measurements of the concentration of a pollutant. Some of these techniques are being used in research projects, but none is accurate enough or practical enough to be used in routine monitoring programs. Ian Galbally of the CSIRO Division of Atmospheric Physics, Victoria, Australia, John Garland of the AERE Environmental and Medical Sciences Division, Harwell, England, and M. J. G. Wilson of Imperial College, London, have demonstrated one such method for dry sulfur deposition. They measured the vertical wind speed and the concentration of sulfur near the surface, both of which varied as turbulent breezes carried gaseous and particulate sulfur into and out of the vegetation. By calculating the net changes, they found that the air lost sulfur to the surface three times faster over farmland than over a forest of Scotch pine. If the latter rate of deposition were to apply over the English and Scottish uplands, they say, dry deposition would constitute 10 to 30 percent of the total sulphur deposited there per year. The absolute accuracy of these flux measurements, the group reports, is on the order of ± 50 percent.

Similar measurements of the dry deposition of acid, even with that kind of accuracy, are impossible at the moment. The workshop report claims that most micrometeorological methods require precise (1 to 10 percent accuracy) or rapid (once per second) analyses of chemical composition, or both. In the case of most substances, especially the various forms of sulfuric and nitric acids, such sensors do not exist. The prospects for directly measuring the dry deposition of acid are "bleak, absolutely bleak," according to Hicks. About dry deposition in general, Hicks is more optimistic: "We can get there. We're only crawling, not walking, but we're crawling very well."—RICHARD A. KERR

Particles deposited on a leaf

The scale bar represents 10 micrometers. [Source: Steven Lindberg]

Critique of Methods to Measure Dry Deposition, B. B. Hicks, M. Wesely, J. L. Durham EPA-600/9-80-050 (Environmental Protection Agency, Washington, D.C., September 1980).