AN UNTIDY WONDER

FOR TWO DECADES A TEAM OF SCIENTISTS HAS BEEN TRYING TO FIND OUT WHAT MAKES A FOREST WORK.

By Jon R. Luoma

PHOTOGRAPHS BY RUSSELL KAYE

Lookout Creek foams over boulders and swirls around huge jumbles of fallen limbs and logs as it rushes through Oregon's Cascade Mountains toward the Pacific. The stream is wild and rugged, not the sort one would normally look forward to navigating without benefit of kayak or rubber raft. It is certainly not the sort of stream to negotiate with only mask and snorkel while in the field of a 1,000-volt electric current. ■ *Yet on a sunny summer day in 1990, biologist Stan Gregory pulled himself crablike along the creek bottom, his elbows and knees and belly scraping and pounding against the rocks and gravel. Nearby in the shallows, a technician in rubber boots waded, a ground wire draped into the stream from the battery pack on his back, an electrode held ahead of him in the water like a droopy fishing pole.* ■ *The electric current, Gregory reported afterward, is unpleasant but not miserable. "Sort of makes your teeth tingle," he said. "Although if you lose concentration and get too close to the probe, you really get a pretty good jolt and you wind up with a metallic taste in your mouth. It's got*

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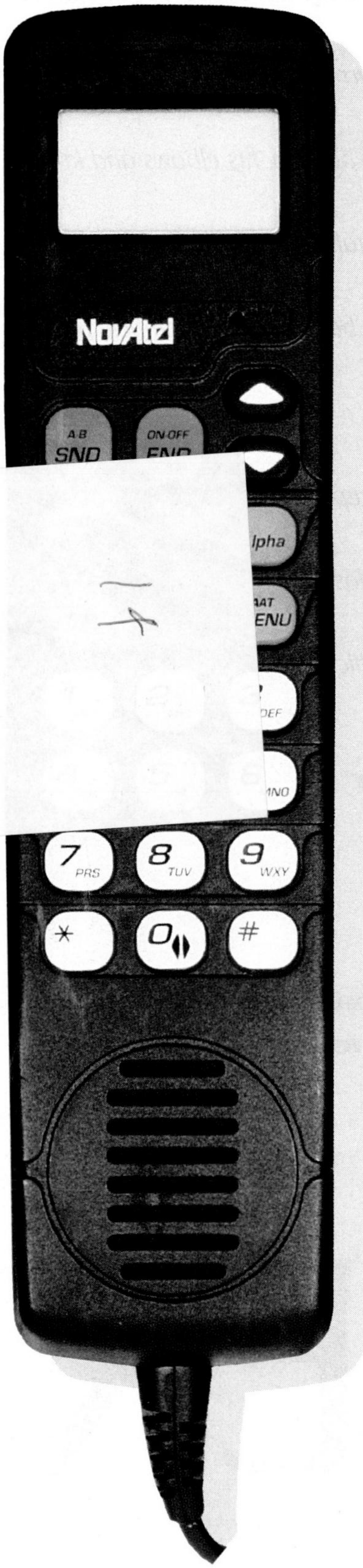

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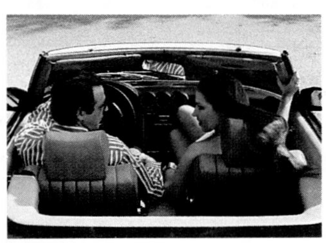

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"TRUFFLES

ARE LIKE A NET,

TAPPING EVERY NOOK

AND CRANNY OF THE SOIL."

something to do with the electricity's effect on your fillings."

Gregory was subjecting himself to this for two reasons, a little one and a big one. The little reason: Fisheries biologists often use electric shock to inventory fish in streams. The amperage is low enough that it only stuns the fish momentarily, bringing them briefly to the surface to be counted. But few biologists had ever looked to see how many fish *don't* respond to the shock and thus never get counted. Gregory and his colleagues in the "stream team," as they dubbed themselves, learned during this adventure that in fact hundreds of smaller fish escape and are never counted, darting just outside the field of current even as a technician moves upstream or down. Some species of sculpins and minnows have apparently been greatly undercounted in traditional stream surveys, giving fisheries biologists a wholly inaccurate picture of ecosystem makeup.

That's good enough science all by itself. But the big reason for Gregory's submersion had to do with a far larger puzzle. He needed to know more about the fish in Lookout Creek because he is part of a team of scientists trying to understand everything that happens in a forest, including the nature of the streams that slice through the woods.

The creek flows through the Andrews Experimental Forest, a 16,000-acre parcel of towering, moss-draped, explosively verdant old-growth Douglas fir and western hemlock. Here, 20 years ago, a team of about three dozen researchers set out to unlock the secrets of an entire ecosystem. They hoped to learn, first of all, what organisms inhabited the forest. But they also hoped they could begin to understand the complex ecological webwork of the forest—the myriad linkages that bind sunlight and rain and drought and earth and everything living, dying, and dead from the depths of the soil to the top of the tree canopy.

They are still decades, maybe even centuries away from that full comprehension. But by now the Andrews forest has become one of the most thoroughly understood ecosystems on the planet. And the researchers here have already discovered that much of what was once firmly believed about how forests function is overly simplified and, in many cases, just plain wrong.

Take, for example, the thousands of immense logs that are continually decaying on the floor of a natural old-growth forest. Like any decaying organic matter, they recycle nutrients into the soil. Yet foresters have long assumed that the rotting logs made a rather small ecological contribution, because compared with the twigs, leaves, and extensive root systems, the logs' wood and bark are poor in nutrients.

"The Forest Service used to spend hundreds of dollars per acre to clean up logs," says Jerry Franklin, an ecologist at the University of Washington's College of Forest Resources and one of the founders of the Andrews ecosystem study. "The primary view was that they were a fire hazard and a waste, that they didn't do anything but cause problems in the forest. No one had considered that, ecologically, the logs might be doing a great deal. In retrospect, it's almost unbelievable that we could have been that stupid."

The Andrews researchers would learn, in time, that huge downed logs in the old-growth forest play a host of previously unsuspected leading roles. One of the most subtle, and surprising, is as a hidden link in a tightly knit ecological chain involving tiny rodents, a pungent fungus, and giant living trees.

The discovery began in the early 1970s with a field trip to the ancient forest organized by Franklin for mycologist Jim Trappe and mammalogist Chris Maser. Trappe and Maser had never met before, and in the car with Franklin that day, Trappe began to tell Maser all about his professional passion: truffles. These fungi, which live deep in the soil, cannot photosynthesize. Instead, the fungal colony actually grows into and penetrates the finest, hairlike rootlets of trees to extract stored sugars from the root cells.

But, as Trappe explained, the relationship is mutual. When roots and fungi combine in such a way, they acquire a joint name, "mycorrhizae." These mycorrhizae work almost as one organism to support both truffle and tree. Fed by the sugars photosynthesized in the tree canopy, the fungi grow long tendrils, called hyphae, thinner than a human hair, which extend in great webs through the soil. Their reach is far more extensive than the root system itself. The fungal hyphae are efficient absorbers of water from the soil. And they are far more efficient than the roots at reaching and extracting the vital nutrient phosphorus, important to all plants for the formation of nucleic acids. Much of the phosphorus is bound up in complex molecules that are not soluble in water and therefore cannot be easily absorbed by cells. But the fungi produce copious amounts of enzymes that liberate the phosphorus and make it soluble. Further, the extensive reach of the mycorrhizal fungi allows a tree to locate more of the nutrient. It is as if the roots are fishhooks, says Trappe, "but the truffles are like a net, tapping every nook and cranny of the soil."

The truffles, Trappe went on to tell Maser, share both the water and the nutrients they extract from the soil with the roots and, hence, with the tree itself. At the same time, they form a sort of protective shield around the roots against disease-causing organisms such as bacteria and can actually infuse the soil with antibiotics. The fungi also secrete a polysaccharide that functions as a kind of organic glue, helping tiny soil particles clump together; that clumping, in turn, creates a looser, more

Previous page: Lookout Creek snakes its way through the Andrews Experimental Forest in Oregon. In neighboring Mack Creek (opposite), fallen logs recycle essential nutrients and provide a home for many species.

open soil environment in which water and oxygen can flow.

Intrigued by all this, Maser mentioned that mycologists and gourmands might not be the only creatures interested in truffles: many of the small mammals he had been studying were eating fungi, and he wondered if truffles made up any part of their diet. Not long afterward, Maser caught a red-backed vole, a small rodent similar to a mouse, and he sent a sample of its stomach contents to Trappe's lab at Oregon State University. Trappe examined it under a microscope and instantly recognized that the stomach was loaded with telltale tiny serrated and ridged fungal spores. The vole's diet, in fact, consisted entirely of truffles.

Trappe and Maser's studies in subsequent months showed that the fungi are a major and nutritious part of the diet of several small creatures, including northern flying squirrels. Analysis of these rodents' fecal pellets showed that millions of tiny reproductive spores passed through their bodies undigested.

As it turned out, there was a good ecological reason for that. Trappe and Maser and a small group of colleagues gradually pieced together a textbook case of a tightly linked circular chain of interdependency: When a giant fir or hemlock tree dies and crashes to earth, it begins to rot slowly. In a century or more its soft, decayed wood becomes habitat for burrowing voles, who in turn subsist on truffles and distribute reproductive spores throughout the forest in their fecal pellets. The fungi that grow from those spores simultaneously provide more food for the voles and work mutually with the new roots of young trees that will grow to towering size and, centuries hence, crash to earth to begin the cycle anew.

This inoculation of the forest with spores is especially critical after a fire or a devastating windstorm. The disturbance may kill many of the trees the mycorrhizae depend on. But even in a raging wildfire, the wet, spongy logs provide refuge for the small rodents that will not only repopulate the forest but also help the forest itself recover by redistributing fungal spores throughout the soil.

Moreover, the Andrews researchers learned, rotting logs in the old-growth forests did far more than house a few voles and truffles. A single acre in a 500-year-old stand may hold 80 tons of logs in various stages of rot. Laced across the forest floor, they help hold soils in place and abate erosion. For some tree species in the region, including hemlocks and Sitka spruce, the logs serve as "nurses" for seedlings. While the seedlings might have difficulty sprouting on the moss-matted floor of the forest, they can easily implant themselves in the soil-like layer of decayed bark, wood, twigs, needles, and other forest litter that accumulates on top of the fallen nurse-log.

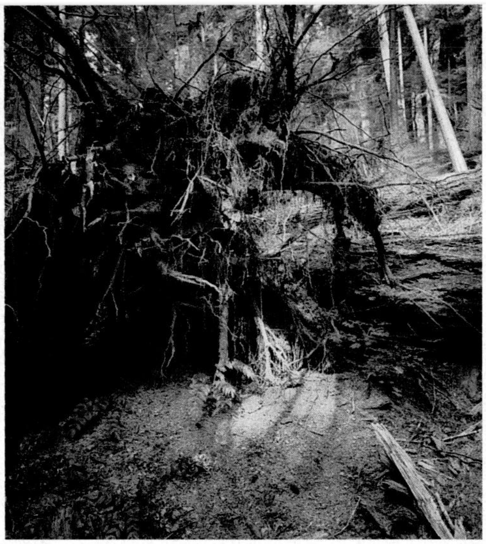
When the logs become extremely decayed, they fragment into pieces that merge with the forest soil. In fact, says Trappe, by sorting the brownish fragments from soil samples "centimeter by centimeter," he and his colleagues learned that as much as half of what appeared to be soil in the forest was actually pieces of rotted log. Those masses of rotted wood, he says, "are spongy and hold many times their own weight in water. They're an ideal niche that rootlets and mycorrhizae can develop in."

This discovery wouldn't have been made without the entire Andrews study. Yet the study almost didn't happen. The Andrews forest was specifically established as an experimental site by the U.S. Forest Service in the 1940s to give scientists a place to conduct research. But research on forests in those days had nothing to do with understanding entire ecosystems—and certainly not old-growth ecosystems, characterized by trees 200 to 1,000 and more years old.

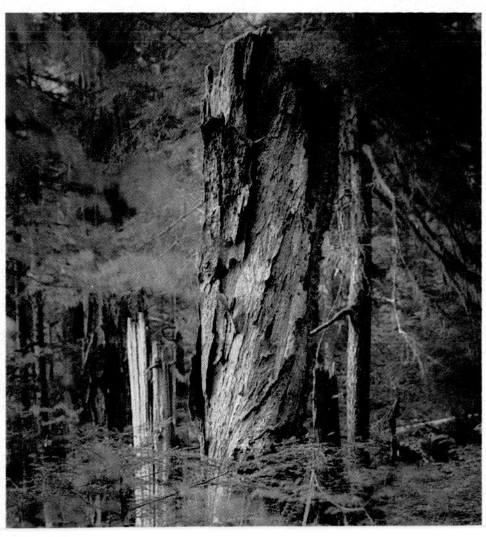
Well into the 1980s both the Forest Service and loggers assumed that virtually all the old growth was going to be sawed down. The conventional wisdom of forestry science was that such ancient forests were "decadent." After all, many of the trees are approaching the end of their long lives. Although their wood is superbly clear, strong, and hence valuable, it is also more susceptible to rot. Individual trees in an old-growth forest might be immensely valuable, but the forest as a whole is in a sort of biological steady state. New trees seed and grow. Old trees die. Acre for acre the forest neither loses nor gains any wood. From a wood-production perspective, the old-growth forest is like a savings bond that has ceased to accumulate interest.

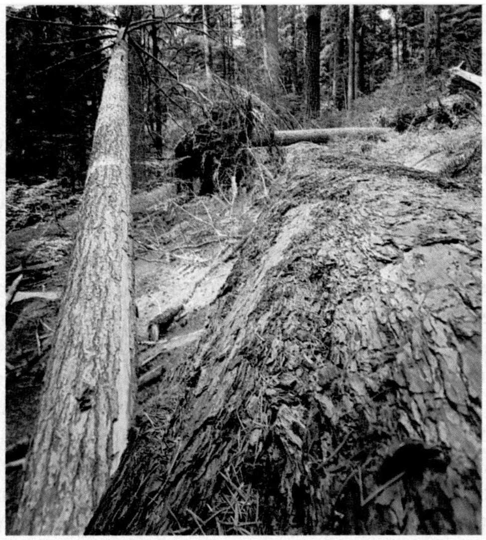
A younger forest, on the other hand, grows more rapidly and accumulates more wood fiber, like interest, every year. So the essence of "scientific forestry" has been to cash in the value of natural forests, replacing them with neatly planted crops of the most economically valuable trees.

By the early 1970s the standard recipe for managing most of the vast public forests in the American West went like this: log out the old growth; burn over the land to clean up the clear-cut site; dose it with herbicides to knock out any unwanted competing plants or trees; and seed the landscape with uniform



Previous pages: Ecologists set climbing ropes to scale giant trees and explore the forest canopy. They also slice "cookies" from fallen logs to measure the rate of decomposition. The fate of this fallen tree (above), like its roots, is entwined with truffles. A dying stump (below) rises from the ground.





Fallen logs (above) provide habitat and refuge for animals such as the cyanide-producing millipede (below). Millipedes, the major consumers of coniferous and deciduous leaf litter in western forests, help speed up nutrient recycling.

plantations of valuable trees, usually Douglas fir. This "thrifty" young (as opposed to "decadent") forest would be managed to promote the maximum growth of that single species.

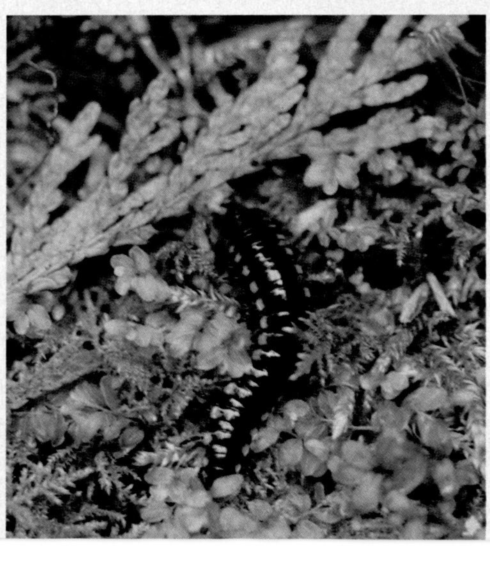
For the Andrews in Oregon, and for other experimental forests, that conventional wisdom dictated that research be focused on regenerating young fir forests. And that, says Franklin, is precisely the sort of science he practiced as a young Forest Service scientist.

But since his boyhood in a pulp-mill town in southern Washington, Franklin had always been fascinated by the wild old-growth forests. "I got this idea," he says, "that it might make sense to study these forests in more detail before they were all gone." In the 1960s he began pushing within the Forest Service for a detailed study of the still-standing expanses of old growth in the Andrews Experimental Forest. His supervisors and colleagues were, to put it mildly, skeptical.

"We had all come through forestry school with terms like 'biological deserts' and 'cellulose cemeteries,'" says Franklin. "Old-growth forests were seen as just sitting there, wasting away. So when I started suggesting that it might be worth taking a hard look at these ecosystems while we still had a chance, people in the profession thought I was completely off my rocker. The attitude was pervasive. People said, 'What in hell do you care about these old forests for? It's obvious that the future is in the young, managed forests.'"

But in 1970 he was able to secure funding from the International Biological Programme, an effort sponsored by the United Nations and the National Science Foundation, to begin a "whole ecosystem" study. That summer a small army of specialists, including botanists, entomologists, mycologists, mammalogists, biochemists, ornithologists, plant and animal ecologists, and others, descended on the Andrews forest.

"It took a while to get our bearings," recalls Fred Swanson, a geomorphologist (he studies landforms and the processes that create them), charter participant in the study, and now Franklin's successor as its leader. The trend in science, he says, had been toward increasingly detailed specialization—"scientists who spent their careers studying the behavior of one species of bug that lives only on the upstream side of boulders in a river." But whole-ecosystem research requires dozens of specialists to weave their knowledge and skills together. "We all came from different fields and, to some extent, we all spoke different languages. But as time went by, there got to be a sort of team spirit. It probably had a lot to do with the fact that we believed what we were doing was important science, even though the scientific establishment didn't give much support to whole-ecosystem studies at the time."



There was quickly such a flurry of activity in the woods that different scientific teams had to begin marking their research territories with color-coded tags. Some researchers began wading the mountain streams; others sampled rainfall, or began cataloging the animal species of the forest—from elk to insects. Entomologists set thousands of "sticky traps" and "pitfall traps" for insects from the soil level to the top of the canopy. Ornithologists, equipped with headsets and radar antennas, began stumbling through the forest by night, tracking a then little known nocturnal predatory bird called the spotted owl.

Others, using modified rock-climbing equipment, ascended for the first time 20 stories into the tree canopy. They sampled temperature, relative humidity, and winds in various microclimates within the canopy. They painstakingly mapped the entire surface of individual trees, from the lichens growing on portions of the trunk to the patterns of needles on each twig.

Much of the canopy work was done by young research assistants willing and limber enough to scale the heights 100 feet or more overhead. But the burly Art McKee, an ecologist and the site director for the Andrews forest, ascended only twice. The first time, for the sheer experience, he climbed a 200-plus-foot-high Douglas fir by means of a pair of ropes disappearing into the foliage perhaps ten stories overhead. The second time, after the first ascent left him with the shakes and "cotton mouth," he scaled the tree to prove to himself he could do it again without terror. "The tree was swaying in the wind," he recalls. "When I got up to the canopy there was a research assistant up there eating a sandwich. She said something like, 'Isn't it wonderful?' I couldn't answer her. I had cotton mouth again."

That tree, and others on the same site, were so intensively mapped and studied that they almost appeared to the scientists to acquire personalities. They certainly acquired names. "This one," McKee says of the tree with the ropes, "is Minerva." Other nearby trees, their craggy trunks so fat that three men could barely join hands around them, were Galadrial and Slim.

The researchers who went aloft learned that the large green *Lobaria* lichens that draped the boughs of the ancient trees did more than simply borrow the limbs as a place to anchor themselves. The lichens actually serve as critical engines that process the fertilizing nutrient nitrogen for the entire ecosystem. All living things in the ecosystem need nitrogen to form proteins, but although nitrogen is abundant in the atmosphere, few organisms can use it directly. The *Lobaria* lichens in the canopy are, like legumes in a garden, able to "fix" nitrogen—that is, reduce it to ammonia and other compounds, which can in turn be used by other living organisms. The nutrient eventually leaches out of the lichens with the rain, or reaches the soil when the lichens are blown out of trees, or rains down, unseen, in tiny microparticles. "There's no doubt that the lichens are a major, and maybe *the* major, contributor of nitrogen to the old-growth forest," says Oregon State University botanist Bill Denison.

"Once you got up in the trees," says George Carroll, a University of Oregon biologist, "it was evident that there was tons of this stuff. It was all over up there." But researchers think *Lobaria* doesn't begin to prosper in the canopy until a forest is about 100 years old—and doesn't thrive until the forest reaches old-growth status. Under current management schemes, forests in the region are being clear-cut long before then. For one or two such rotations the forest may be able to rely on the bank of nitrogen stored in the soil, notes Denison. But in the long run, he says, continual rotation may deplete the soil of nutrients the trees need for growth. "If we don't care about our grandkids, we should continue doing what we're doing," Denison says. "If we do care, what we're doing may be managerial folly."

As an antidote to such folly, several of the Andrews scientists have begun calling for what Jerry Franklin first dubbed the "new forestry" and what is now referred to by the less catchy phrase of "ecosystem management." The essence of the idea is that if foresters are going to remove timber for lumber and pulp, they should do it in a manner that mimics what the Andrews group and other ecologists have discovered about nature's own processes. It means that, as would a fire or windstorm, loggers should remove only *some* of the mature trees and leave in place enough "biological legacies"—standing green trees, dead trees, tons of rotting logs, and complex webs of old-growth fungi, plants, insects, and mammals—to help the forest recover naturally. It means avoiding wholesale clear-cutting of sites and not dosing these sites with herbicides to remove competing plants. As new seedlings grow on a site, and the forest begins to recover, the rotting logs would remain on the forest floor, along with the mycorrhizae and small rodents. As the new forest matures, it would become diverse in structure, with many young trees but also with still-living immense trees to support a wide range of other plants and animals.

The approach is quite controversial, and some loggers and many environmentalists decry it, the former because it means less timber taken from forests, the latter because it could mean some timber taken out of old-growth forests that might otherwise be totally preserved. But already the second-largest wood-products company in the region, Plum Creek Timber, is applying the new-forestry approach on about 20 percent of its land. Weyerhaeuser, the region's largest company, is experimenting with the techniques, too, on a smaller scale.

The Willamette National Forest (below), a "managed" woodland next to the Andrews, is neatly harvested and pruned of excess growth. After timber is taken from the Andrews (opposite), stumps and other debris remain, making contributions to the cycle of regrowth.

THE NOTION OF PRODUCTIVE OLD GROWTH FLIES IN THE FACE OF THE CLEAN-IT-UP WISDOM OF LOGGING.

This June, U.S. Forest Service chief Dale Robertson ordered all 122 national forests to begin using ecosystem management techniques such as those developed in the Andrews. The Andrews team is now working directly with foresters on the nearby Willamette National Forest, trying to determine the natural fire history, going back about seven centuries, of a 19,000-acre parcel. Their idea is to design a selective logging program whose effect is similar to that caused by the natural pattern of fires.

In the Andrews itself, work continues. At one site, hundreds of immense logs, brought into the Andrews from a nearby commercial cut, have been lined up on the forest floor as part of an experiment by researcher Mark Harmon. The study is extraordinarily optimistic: it's expected to last at least 200 years. Every few months Harmon is slicing small rounds—"cookies"—from the ends of the logs and analyzing the wood to study the rate and nature of their decomposition, a process that takes centuries in some tree species. From such studies, researchers in another era may be able to determine, among other things, just how much nutrition rotted logs eventually contribute to the forest environment.

This year the researchers have moved into some new areas, including the study of economic benefits other than lumber and pulp that might come from forests. Mycologist Randy Molina, of the Forest Service's Pacific Northwest Research Station, and a group of colleagues have begun investigating the potential of Northwest forests, both old growth and new, to provide a sustainable harvest of gourmet-grade mushrooms and truffles for the huge mushroom markets in Japan and Europe.

Molina reports that in just the past six years the Pacific Northwest has developed a forest mushroom industry worth between $10 million and $20 million annually. He suggests that some expanses of the damp old growth might be able to produce far more income, and far more *sustainable* income, as mushroom farmland than as clear-cut timber acreage. In fact, he says, "*any* highly productive forest might produce more income from these mushrooms year in and year out for 70 years than from one timber harvest at the end of a 70-year logging cycle."

The whole notion of productive old growth flies in the face of the conventional clean-it-up wisdom of logging. "It's hard for people stuck with this concept of tidy agricultural forestry to accept," admits Jerry Franklin, "but we're trying to suggest that a little bit of chaos is a wonderful thing in a forest." D

TIME reve

Can you tell the past from the future? Physicists can't—not yet, anyway.

By A. Zee

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