ously," and those words have caused Jones and his colleagues to see red. "We shouldn't have commodities groups with political muscle dictating what research we do at UC," Jones says.

Nor should Farrell's office be dictating such priorities, say others. "The faculty…feel that matters of academic policy—like moving programs from campus to campus—are something that falls under the authority of faculty review," says plant biologist Taylor. Even administrators at UC Davis, a campus that stands to gain resources in the rearrangement, are opposed to Farrell's proposed reshuffling of resources on those grounds. "We're talking about academic programs here," says acting Davis chancellor Larry Vanderhoef. "The plan has to derive from the deans and the faculty who do the work."

Farrell, however, counters that since the controversy concerns state-wide research funds, the decision about the way to spend them lies with the president's office. And Farrell contends that Berkeley stepped over the line when it undertook its reorganization without responding to his input on the process. "I gave input in a very careful, enlightening manner," he told the faculty at his meeting with them last month. But the college, he says, didn't respond. "Not one word of feedback ever, not one word of acknowledgement, not one opportunity for interaction was ever presented, to my knowledge."

Among Farrell's supporters is retired Berkeley potato pathologist Albert Weinhold, who opposed the Berkeley reorganization and served in Farrell's office shortly before retiring last year. Farrell's move, he says, addresses important agricultural concerns. "There are a lot of real serious insect problems, pest problems, weed problems [facing] just about any commodity you can mention," he says. "These need attention." Since Berkeley no longer focuses on such issues, says Weinhold, it has less of a claim to AES funds.

Some observers see the conflict as generational. "There is the old guard, which can see nothing but typical production agriculture research," says Robert Burris, a retired agricultural biochemist from the University of Wisconsin, who chaired a committee of scientists that reviewed—and blessed—Berkeley's reorganization. "You have to move with the times, and Berkeley is trying to do that."

But trying is no guarantee of success. Farrell has invited faculty input on his plan but has let it be known that the final decision will come from his office, probably sometime this spring. Farrell says that Berkeley may be able to negotiate for some unrestricted instructional funds to make up in part for the lost AES money. But beyond the outcome in this one case, the larger conflict over AES funds looms, and there's no simple resolution in sight.

–Marcia Barinaga

ECOLOGY

Biosphere 2 Makes a New Bid for Scientific Credibility

To the believers, Biosphere 2 was the boldest ecology experiment ever. When the first crew of the self-contained ecosystem closed its airlocks behind them in late 1991, Biosphere organizers and a few outside scientists promised that the miniature world would nurture new insights into the workings of planet Earth. But many observers were skeptical from the start, and when the eight "biospherians" emerged from their 2-year sojourn last fall, they were greeted by grumbling that the $150 million, privately funded project in the Arizona desert had produced little of scientific value. Last Sunday, a second crew took its stations, and Biosphere's organizers promised that this time around, things will be different.

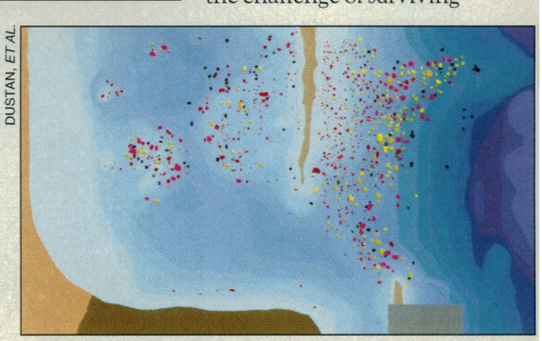
To accommodate more research, the project's managers have thrown open Biosphere's doors to outside scientists. During the first mission, researchers had to rely on the biospherians to collect samples and data—a restriction that limited the number and scope of the projects. But during the next 10-month mission, anyone wanting to pursue research approved by Biosphere 2's parent company, Space Biospheres Ventures (SBV), will be free to live and work inside the facility for anything from days to months. With that policy change, claims John Corliss, the project's scientific director, "Biosphere comes into its own as a powerful laboratory." He argues that the biospherians and their guests are now set to do serious scientific work on everything from the production of trace gases by plants and the soil to the factors controlling the buildup of leaf litter in mangrove swamps.

GONZALO ARCILA/SPACE BIOSPHERES VENTURES

Or are they? The new open-doors policy isn't mollifying scientists who feel that the Biosphere 2 managers are squandering the scientific promise of their facility, an engineering marvel that is the largest closed life-support system ever built. From the outset, these critics have complained that the project suffered from a lack of scientific planning, inadequate peer review, and excess secrecy. A low point came in February of last year, when the 11 members of a science advisory committee resigned en masse, claiming they had been left out of key decisions (*Science*, 19 March 1993, p. 1688). "It's a mini-supercollider that's being wasted," says Gerald Soffen, director of university programs at the NASA Goddard Space Flight Center, who was a member of the advisory committee.

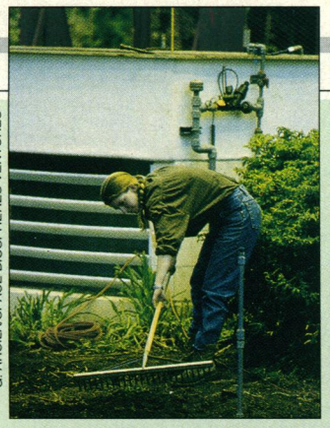
Soffen calls the decision to accommodate visiting researchers "a step in the right direction." It's little more than a Band-aid, though, he and other critics say. "They can [now] get a lot of people to tinker in there," says geochemist Wallace Broecker of Lamont-Doherty Earth Observatory, who has directed some experiments at Biosphere and extols its potential for studies of how high carbon dioxide levels affect plant metabolism and soil composition. But he and others say the underlying problems are still there—and Soffen says they flow from a deeper malady. Biosphere's founders, he says, are "mixed up with theater," more eager to create an emblem of new-age environmental consciousness than they are to do science.

More sympathetic observers like biologist Harold Morowitz of George Mason University argue, however, that Biosphere shouldn't be expected to provide "hard-nosed, data-driven science." These observers point out that the biospherians and many of the scientists associated with the project have, as geneticist John Avise of the University of Georgia puts it, "a lot of things to preoccupy them other than cold, hard biology." Chief among them, they say, has been the challenge of surviving



DUSTAN, *ET AL.*

Ocean in miniature. Biosphere's 40-meter-long ocean *(top)* and a map of its corals.



G. ARCILA/SPACE BIOSPHERES VENTURES

Hard labor. Eking a living from Biosphere's gardens.

No Eden in Biosphere

As any gardener can tell you, it takes a lot of work to maintain a balanced ecosystem. The eight crew members who spent 24 months isolated in Biosphere 2 don't need to be reminded: It took virtually all their waking hours to feed themselves and keep their environment in order. That's one reason, say Biosphere organizers, that few scientific results have come out of Biosphere—though critics point to deeper problems (see main text).

When the biospherians emerged last fall, lean and tired, they could point to several major achievements. The facility had proved an engineering marvel, losing just 9% of its atmosphere a year—an impressively low figure for a 3.15-acre building that one researcher describes as shaped "like an octopus with lumps." The biospherians recycled all their waste and water and produced 80% of their food, making up the difference with supplies stored at the beginning of the mission. And several components of the miniature world, including the marsh, coral reef, and ocean, have been pronounced healthy by researchers surveying the facility.

But Biosphere proved that a sealed world may not be an eden. Best known are the woes of the biospherian atmosphere, which became so rich in carbon dioxide that engineers had to install a scrubber to cleanse it, and so depleted in oxygen that they had to provide regular oxygen infusions. What threw the atmosphere out of kilter, as Jeff Severinghaus and Wallace Broecker of Lamont-Doherty Earth Observatory and other geochemists determined last year, was the compost-rich soil in the project. As soil microbes oxidized the organic matter, they drained oxygen from the air inside the dome and released carbon dioxide.

Besides suffering headaches and shortness of breath from the oxygen loss, the biospherians also went hungry. The productivity of their gardens fell short as pests burgeoned and the Arizona sunlight, already attenuated by the glass and steel greenhouse, was further weakened by a run of unusually cloudy weather. The result was drastic weight loss—an average of more than 25 pounds over one 6-month period for the men.

Added to those burdens was the challenge of trying to keep the wild ecosystems healthy. To keep down algae growth on their reef, the crew had to pick off "bags and bags" of seaweed, says Phil Dustan, a reef expert at the College of Charleston who monitors Biosphere's corals. They had to eliminate rogue species, such as the lobsters that were devouring other organisms in their ocean and the vines that threatened to choke the wilderness. And they had to pollinate plants by hand after bees and other pollinators died out, along with two-thirds of the 300 insect species originally introduced into the dome. Some insects, unfortunately, did exceptionally well: The cockroach population exploded, as did a species of black ant accidentally introduced into the enclosure.

Biosphere 2 may not have taught many lessons about biosphere 1, the outside world. But it has left no doubts about how hard it is to build a working substitute. Says Don Spoon, a microbe expert who recently left Georgetown University to join Biosphere as a staff scientist, "You have to play God, and that's not easy."

–T.A.

in Biosphere and making it work as a self-contained ecosystem. During the first mission, the biospherians had to cope with high carbon dioxide and low oxygen levels, difficulties in growing crops because of pest invasions and cloudy weather, and endless drudgery in maintaining their habitat (see box).

With all that to contend with, says Corliss, "there wasn't much time for biospherians to do research." The next crew, he points out, should have it easier. Technicians will continue adding oxygen to keep the air breathable. New plant species introduced during the transition period should soak up some of the carbon dioxide as they build their woody stems. And shade-tolerant crops like bananas, cassava, and taro, artificial lights in the gardens, and toads and geckos to control pests should bolster the food supply.

Those steps should leave the crew more time for activities other than growing their food and weeding their wilderness. And scientist-guests will, except for several hours a day of work in the agricultural area, be free to pursue research. That should permit more of the kind of small-scale experiments several researchers set up in Biosphere last time around. Before the first occupation, for example, Avise and his student Kim Scribner released two closely-related species of mosquito fish into the freshwater pond to study hybridization between them, a process that might happen in nature. And Jeff Severinghaus of Lamont, Broecker, and others have been analyzing vegetation to see how the high carbon dioxide levels affect the ratio of carbon isotopes taken up by plants.

Publications have been sparse so far, however. Corliss promises "major results" from a large-scale survey of plants and animals during the 6-month transition between the first and second missions. He also stresses the promise of other studies that are just getting started, including analyses of reactive gases given off by the plants, studies of human physiology, and video observations of root growth. But Soffen, Broecker, and others think those mostly descriptive studies don't use Biosphere to its full potential. Instead of operating the facility to answer specific questions about the interactions between organisms, soil, and atmosphere, Soffen says, its managers have opted for something "more like 19th-century natural history: 'Let's see what's there and we'll record it.'"

Some outsiders would like to conduct experiments that would require manipulating the composition of Biosphere's atmosphere or even partitioning the facility into smaller ecosystems. But a researcher familiar with the project, who asked not to be named, says Biosphere managers are reluctant to agree to such steps because of what he calls their "pseudo-holism. They believe that you shouldn't try to test for effects individually; they consider that reductionism." Instead, they prefer to let the system run with minimal interference. "They're hoping something will pop out and grab them," adds Broecker. To Broecker, the only hope for the facility to reach its full potential is for SBV to set up an independent research institute, able to solicit and evaluate research proposals on its own.

There's no need for that, says Corliss. "If we decide we need more input from outside scientists, we'll get it." He argues that "a detailed, laid-out plan" can blind researchers to surprises, and he defends the current mix of modest experiments and patient data collection by pointing out that Biosphere is the first facility of its kind; it's too early, he says, to be sure just what questions it can be focused on most profitably. "In some respects you're exploring unknown territory."

He adds that some of the criticisms reflect "frustration on the part of outsiders, who can think of all the things they'd like to do in Biosphere." And there Corliss and his critics are in perfect agreement. Says Broecker, "To design good science in there isn't easy, but it could be done—and should be done."

–Tim Appenzeller