The most important result to date, says Schlesinger, is that trees in the high-CO_2 plots grew 25% faster than controls did during the first three growing seasons of the experiment (*Science*, 14 May 1999, p. 1177). Last year, however, the difference between the experimental and control stands "was not as great" as it had been from 1997 to 1999, suggesting that the initial boost CO_2 gives to the growth rate of trees may not be sustained once other nutrients such as nitrogen begin to run out.

By November, Schlesinger expects to have results from this year's growing season—and a much better idea of how at least one forest tree species will respond to high CO_2 levels over the long run. The answer is critical to ongoing policy debates. Some partisans argue that faster growing forests will provide a sink for the excess CO_2 humans produce, but "our experiments are suggesting that forests will soak up some of the excess carbon dioxide but nowhere near all of it," says Schlesinger. And Harvard University biologist Fakhri Bazzaz, who also studies vegetative responses to CO_2, estimates that higher levels of the gas will boost the growth rate of the world's plants by only about 10%—far less than what would be needed to balance the global carbon budget.

High CO_2's impact on pine fecundity turned out to be even more dramatic than its impact on growth—onset of reproductive maturity at smaller sizes and 300% more cones and seeds than controls. In addition, trees in the high-CO_2 plots were producing more seeds than were trees of the same size in control plots, suggesting that they were putting a higher percentage of their carbon currency into reproduction.

Early reproduction could also cause the trees to grow old and die sooner, reducing the amount of carbon they sequester. But for *Pinus taeda*, the study's results may be good news—and spell trouble for its competitors. Scientists have hypothesized that faster growing species such as pine will respond more to elevated CO_2 levels than will slower growing hardwoods. If this turns out to be true, "we would expect to see dramatic changes in forest community composition," says LaDeau.

According to Bazzaz, simulation models predicting the effects of elevated CO_2 levels 150 years from now do show a trend of decreasing species diversity over time. And in a still-unpublished meta-analysis of 170 studies of reproduction in herbaceous plants, mostly crops, Curtis found that fast-growing, high-yielding species—equivalent to loblolly pines—profited more from high CO_2 levels than did slow-growing plants. "My suspicion is that forest communities will become less diverse as aggressive, fast-growing trees become more abundant," he says. Such shifts in tree composition would have cascading effects throughout the ecosystem. Some pollinating insects and birds, for instance, may end up with more food and others with less, changing the abundance and distribution of these animals as well as other species that rely on them.

It is way too soon, of course, to say whether any of this actually will happen. Among the Duke researchers' next steps is to examine the viability and quality of the seeds their experimental pines produced. They also are waiting for a handful of hardwoods growing in each plot to reach maturity—as well as those at an all-hardwood FACE site in Tennessee—so they can examine these trees' reproductive responses to CO_2.

But even following through on FACE experiments may never reveal how real forests will react to high CO_2 levels. The Duke plots "are pine plantations, not forest ecosystems," says Bazzaz. Teeri agrees that "what we really need are long-term studies of significant expanses of natural forest." Researchers had hoped to conduct such mega-experiments soon, but Congress last year did not fund a $12 million request from the National Science Foundation to launch a National Ecological Observatory Network. For now, Duke's loblolly pine experiment—and others like it—may offer the best evidence of how forests will respond to CO_2 buildup in the next half-century. **–LAURA TANGLEY**

Laura Tangley is an editor at *National Wildlife* and *International Wildlife*.

CREDIT: ADAM WILSON

SCIENCE IN BRITAIN

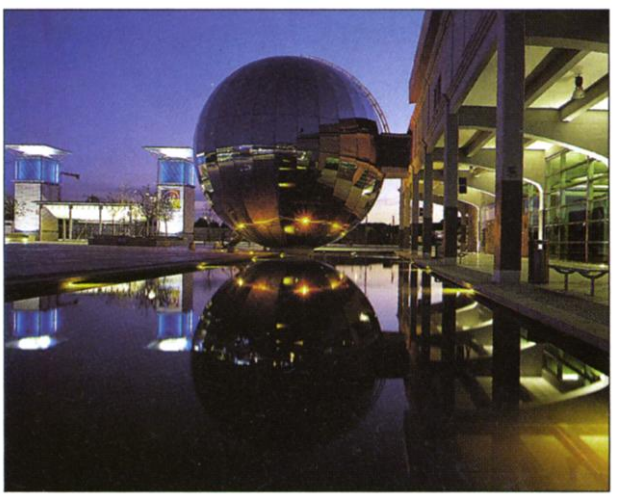
Science Centers Blossom, But How Many Will Survive?

Hands-on science exhibits are springing up across the U.K. Now, they're all part of an unplanned experiment: survival of the fittest

BRISTOL, U.K.—Inside a huge, five-story greenhouse on the waterfront of downtown Bristol, tropical birds and butterflies flit above a botanist's wonderland. Glistening in the humid enclosure are species representing key events during 500 million years of plant evolution—from primitive liverworts and velvety mosses through horsetails, ferns, and conifers, on up to the flowering plants. Scientists laud the "Wildscreen" exhibit, saying that it vividly brings science to life. It's "a marvelous project," says Thomas Eisner, an ecologist at Cornell University. "It's exactly what is needed to kindle an interest in nature and the spirit of conservation."

Wildscreen is part of a phenomenon that's sweeping the United Kingdom. Fueled by $1.4 billion in national lottery revenues and matching funds, 10 science centers—including @Bristol, which houses Wildscreen—have opened their doors to the public since July 1999, and another seven are scheduled to get going in the next year. Created to mark the new millennium, the gleaming new edifices are replacing such urban chancres as derelict steelworks and neglected quays. From the National Space Science Centre featuring a Soyuz rocket to the model ecosystems inside the Eden Project's multiple linked geodesic domes—tall enough to enclose the Tower of London—the science centers offer much more than inner-city renewal, says @Bristol chief executive John Durant. "This is an amazing opportunity to change the scientific culture of a country and connect the community closely ... to the world of science and technology," he adds.

But the science centers must count on a healthy patronage if this budding British renaissance in bringing science to the public is to succeed. The Millennium Commission, a quasi-governmental body that has funded the start-up of the 17 interactive science and technology centers (see table), has stated from the get-go that it will not provide operating money for its progeny. Once the initial funding has been exhausted, the centers are vulnerable to collapse—and that's not neces-



On a roll. The Orange Imaginarium, a planetarium sponsored by the Orange corporation as part of @Bristol.

sarily a bad thing, some argue. "Only the better schemes will survive," says David King, chief scientific adviser to the U.K. government. "That's what survival of the fittest is all about."

Millennium fever

Mandated to spend $3.2 billion in profits from the U.K. lottery, the Millennium Commission ended up doling out 21% ($390 million) to science-based projects, with commercial sponsors—a requirement—kicking in more than $1 billion more. The United Kingdom hasn't had an investment in science communication on that scale since proceeds from the Great Exhibition in 1851 were used to set up several major British institutions, including the precursors to London's Science and Natural History Museums, says John Beetlestone, founder of Techniquest, one of the few U.K. science centers started before the lottery bonanza.

Distinguished from museums by their emphasis on hands-on exhibits and lack of specimen collections, science centers first got going in the late 1960s, when the San Francisco Exploratorium and the Ontario Science Centre in Toronto were created. "The U.K. has been a relative latecomer in this area," Beetlestone says. The concept took root in the United Kingdom only in the 1980s, with the launch of three centers aimed at elementary school children: Techniquest in Cardiff, the Exploratory in Bristol, and Launchpad, a hands-on exhibit in London's Science Museum.

The lottery funds have shaken up the status quo. "The movement has changed from being a tiny crusade amongst a lonely group of enthusiasts, to something of a national movement," says Durant.

In general, the new centers are receiving high marks for science content. Many have links to universities. For example, the Institute of Human Genetics at the University of Newcastle-upon-Tyne has moved its entire faculty (150 researchers) into new labs down the road at the International Centre for Life. And the National Space Science Centre, designed with the help of researchers at the University of Leicester, will house mission control for CATSAT, a satellite built partly by students under supervision from Leicester researchers.

"The initial quality of the centers looks high," says Peter Cotgreave of the Save British Science Society. Not all scientists are impressed, however. "I'd like to see a lot more science in the new centers," says University of Bristol neuropsychologist Richard Gregory, founder of the Exploratory, which was replaced by @Bristol.

Financial uncertainty

Like young salmon, not all the hatchlings are expected to survive. Casting a shadow over the lottery-funded projects is the much-panned Millennium Dome, a nearly $1 billion exhibition in Greenwich that drew far fewer visitors than expected. But the dome is not the only 2000 baby to flounder: The National Centre for Popular Music in Sheffield has gone bankrupt, while the Earth Centre in Doncaster—the first science center driven to the financial brink—has closed temporarily, apparently to save money through restructuring after the number of projected visitors was cut by half.

Many observers worry that the Earth Centre's woes are only the beginning of a wave. Part of the problem is that the commission funded each proposal on its merits, without judging how many science centers a single island nation might support. "The Millennium Commission didn't have any experience with science centers, so they really didn't know how to rationally decide which proposals to fund and which not to fund," says Techniquest's Melanie Quin. "I fear visitor numbers will not be met simply because the centers conducted feasibility studies in ignorance of all the others."

And some of the feasibility plans are considered suspect. "In some cases, business plans were the product of market researchers sticking a wet finger in the air," Quin says. "There has been an underestimation of what is needed to run and what is needed to invest," adds Goéry Delacote, chief executive of San Francisco's Exploratorium.

Whatever their initial promise, all the science centers now face a huge fund-raising challenge. "I don't know of a science center anywhere in the world that is meeting 100% of its running costs from commercial sources," says Durant, who notes that visitor revenue covers 20% to 75% of a center's operating costs. "Education costs money and does not pay its way."

Some centers have done well in luring corporate sponsors; for instance, @Bristol's stable includes the European telecom giant Orange, which put up $5.7 million over 5 years for the Orange Imaginarium, an immense steel-hulled planetarium.

Another financial hurdle is that, in order to remain fresh, science centers must change their exhibits every 3 to 5 years—a considerable expense beyond running costs. The Millennium Commission may be poised to help out, however: It is discussing a set-aside of $35 million for the development of new exhibits at existing science centers. "The proposal is still at an embryonic stage at the moment, but the idea and the willingness are there," says the commission's Nina Baxter.

Rather than compete with one another, the science centers have banded together to lobby for more money. With start-up funding from The Wellcome Trust, they have formed a U.K. branch of the European Collaborative for Science, Industry, and Technology Exhibitions.

"I would be surprised if all the centers turn out to be a major success," says Cotgreave. "But even if only some turn out that way, then it will all have been well worth it." —JOHN PICKRELL

THE LOTTERY'S SCIENCE PROGENY

Center	Location	Funding* ($ millions)	Opening Date
Millennium Point	Birmingham	$72.20	September 2001
The Odyssey Project	Belfast	$64.98	March 2001
@Bristol	Bristol	$64.04	July 2000
The Eden Project	Cornwall	$57.76	March 2001
The Earth Centre	Doncaster	$56.80	Closed for restructuring
Glasgow Science Centre	Glasgow	$50.54	June 2001
International Centre for Life	Newcastle	$45.41	May 2000
The Millennium Seed Bank	West Sussex	$43.32	November 2000
National Space Science Centre	Leicester	$33.65	June 2001
National Botanic Garden of Wales	Carmarthenshire	$31.33	May 2000
The Deep	Kingston-upon-Hull	$26.71	Summer 2001
Our Dynamic Earth	Edinburgh	$22.82	July 1999
Magna	Rotherham	$22.53	April 2001
The Big Idea	Irvine	$8.09	April 2000
INTECH 2000	Winchester	$6.80	Fall 2001
Making It! Discovery Centre	Nottinghamshire	$2.51	February 2002
Sensation	Dundee	$2.31	July 2000

* From Millennium Commission.