that the Duke Island pluton formed 3400 ± 1300 kilometers to the south.

That finding "agrees almost exactly with results from the Coast Cascade Belt by us," notes Wynne. "If you had just that result to build this large-displacement case, you would be on weak ground, but it would be a remarkable coincidence if they went through all those machinations and still got a result that agreed with ours."

No common ground

This one-two punch has left the geologists unfazed—and ready with some counterpunches. At the GSA meeting, Mustard reported that he and his GSC colleagues studied the origin of 75-million-year-old sediment in the Nanaimo basin of southwest British Columbia. The sediment fans out to the west, showing that it had washed down from the east. As a result, its mineral grains should yield clues to where the terrane was docked 75 million years ago. If it lay next to Mexico, the zircon grains in the sediment should be about 1 billion years old, the most common age of the Mexican rocks that would have been eroded to supply the sediment. If British Columbia were instead about where it is now, the zircons washed in from the east would be more than 2 billion years old.

In fact, uranium-lead dating of the Nanaimo zircons showed them to be on the old side, Mustard reported. "Certainly the zircons we got are the ones you would expect to get from maybe 500 kilometers [to the south] or even up to 1000 kilometers, but nothing like 3000 kilometers."

Marine fossils in coastal rocks are also offering preliminary evidence against a distant origin for terranes. If the rocks originated far to the south, the mollusk fossils and radiolarian microfossils they contain should represent warmer-water species. But most of the 145- to 100-million-year-old fossils that James Haggart of the GSC in Vancouver and Elizabeth Carter of Portland State University in Oregon studied were characteristic of temperate and northern latitudes, suggesting the terrane has largely stayed put.

The geologists and their paleontologist allies say they won't stop there in their effort to counter the latest volley from the paleomagnetists. To Margaret Rusmore of Occidental College, this competitiveness is one of the beauties of the controversy. Rusmore, a structural geologist who works in British Columbia and is married to paleomagnetist Scott Bogue, sees the dispute from both sides: "It's amazing how riled up people can get about this at meetings. It's great; it's spurring a lot of good research, and eventually I think we'll come up with some sort of resolution."

Unless geologists and paleomagnetists change their stripes, however, that resolution will come only when both kinds of evidence finally agree. As geologist Vicki L. Hansen of Southern Methodist University notes, neither side is likely to change its standards of evidence: "It's kind of like religion."

–Richard A. Kerr

Additional Reading

D. S. Cowan, "Alternative hypotheses for the Mid-Cretaceous paleogeography of the western Cordillera," *GSA Today* **4**, 184 (1994).

OPHTHALMOLOGY

Envisioning an Artificial Retina

A speck in your eye usually obscures vision. But now researchers in Boston are trying to reverse the usual order of things. They've placed a speck of microelectronics in rabbits' eyes that might—eventually—have a vision-enhancing effect in humans, restoring sight to some blind people.

The speck is a tiny microchip that sits at the back of the eye, and it's designed to translate visual information into electric pulses that are sent to the brain. The device would be a partial substitute retina, a prosthesis for people who have lost the eye's light receptors—the retina's rod and cone cells—through diseases such as retinitis pigmentosa, which affects 1.2 million people worldwide, and age-related macular degeneration, the leading cause of blindness in the West.

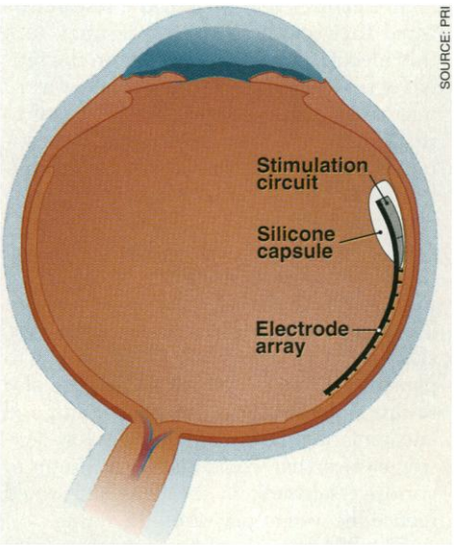
There are researchers who doubt this ambitious goal can be achieved. But in March, scientists on the Project for a Retinal Implant (PRI), a joint effort of the Massachusetts Eye and Ear Infirmary, the Massachusetts Institute of Technology (MIT), and Harvard Medical School, completed experiments that offered considerable encouragement. They finished a series of brief in vivo trials of prototype retinal implant components in rabbits. The test devices delivered tiny electrical currents to ganglion cells—the nerve bodies on the inside surface of the retina that feed into the optic nerve—and produced measurable activity in the visual cortex of the animals' brains.

These results, say some scientists who are following the research, reflect glimmers of the project's eventual success. "If they can create an effective interface and there are viable ganglion cells, they should be able to produce a partial retinal replacement," says Terry Hambrecht, a physician and electrical engineer who heads the Neural Prosthesis Program at the National Institute of Neurological Disorders and Stroke.

But those are still big "ifs," for even the PRI researchers acknowledge that the uncertainties at the interface between technology and human tissue are legion. "We're facing a number of very significant obstacles, one after the other," says Joseph Rizzo, a neuro-ophthalmologist at the Massachusetts Eye and Ear Infirmary and lead PRI investigator.

The problems fall into three main categories. First, researchers still have to determine how healthy ganglion cells are in the eyes of blind human beings. Second, the scientists need to develop an implantable chip that won't tear or poison the delicate retina. Finally, they must face the biggest problem of all: getting the chip to package visual information in a form the brain can use. And there are certainly researchers who don't believe these problems can be solved. Peter Schiller, a neurophysiologist at MIT, says he doubts any implant will be capable of mimicking retinal output well enough to produce anything resembling normal vision. In the face of such skepticism, the PRI team has not pursued large-scale funding, hoping to first bolster their case with small pilot projects.

What they hope to end up with is a prosthesis that includes a camera, mounted on eyeglasses, that captures visual images with an electronic analog to film known as a charge-coupled device. The device would digitize the images, and the information would be beamed via laser onto the retinal implant. Exploiting an attached electrode array, the chip would convert the laser pulses into a pattern of electric signals. In theory, these signals would then stimulate the nearest ganglion cells, which transmit the information to the optic nerve and the brain, enabling the wearer to perceive an image.



Implant in progress. This microchip assembly could substitute for a damaged retina.

This vision, however, depends on there being enough healthy ganglion cells remaining to transmit the information to the brain.

In this area, there is encouraging news. Last October, at the National Institutes of Health (NIH) Neural Prosthesis Conference, a team at another project, the Intraocular Prosthesis Project (IOP) at Johns Hopkins University Hospital in Baltimore, reported on work with three volunteers who had been blinded by retinitis pigmentosa. The retinas of the volunteers were stimulated in one of four quadrants with handheld electrodes, and the people saw phosphenes—points of light—in the corresponding quadrants of their visual fields. This indicated that ganglion cells were still passing signals—and spatially appropriate signals at that—to the optic nerve. "The ganglion cells are functioning in about 70% of their normal numbers in patients with outer-retinal degeneration," says Hopkins ophthalmologist Eugene de Juan.

That brings up the next problem: creating an implant that won't harm the retina. This tissue, says John Wyatt, an MIT electrical engineer and Rizzo's co-principal investigator, has the mechanical properties of "about one layer of sticky wet Kleenex." And that doesn't make things easy, as the implant's electrode array, made of polyimide plastic 50 microns thick, has razor-sharp edges. Before insertion, therefore, the array is coated in silicone and bent to match the retina's own curve, so that it rests on the surface without gouging.

In February and March, the researchers wired their prototype electrode array to a thin electric cable and placed it on the retinas of seven rabbits. A stimulus as low as 10 microamps per electrode—a level equal to that envisioned for a permanent, self-contained implant—generated electrical activity in the visual cortex, measured by scalp electrodes. The implants were removed after a few hours, but later this year the PRI group hopes to show that the prototype can be left inside a rabbit eye safely for days or weeks. The group will then graduate to tests in dogs, and—in 5 to 7 years, if all goes according to plan—to humans. The researchers are also testing alternative materials for building and encapsulating the implant, such as low-density plastics, that would be more resistant to corrosive saltwater in the body and would reduce the weight placed on the retina.

The PRI team is putting off the final problem—the electrical interface with the brain—until the device is ready to be implanted in humans. Wyatt explains that optimizing the frequency, timing, and spatial distribution of the electrodes' stimuli to produce useful images will require feedback from experimental subjects; in short, the researchers will have to ask people what they see.

Wyatt is cautiously optimistic that the groundwork laid by the present experiments will pay off. Although ganglion cells come in specialized varieties that respond to many different aspects of visual stimuli—including color, duration, and direction of movement—he says the experiments at Johns Hopkins make it reasonable to suppose that "if you stimulate the ganglion cells in an X pattern, you'll see an X." De Juan and his colleagues at Hopkins are exploring this further. The scientists are stimulating the retinas of their volunteers to determine how much current must be applied to make human ganglion cells fire and how closely together electrodes should be placed ro achieve maximum visual resolution.

Not everyone is sanguine about this approach. Schiller, for instance, thinks it's far too simplistic to expect that placing a relatively crude array on top of the highly differentiated ganglion cells will cause the cells to fire in an interpretable pattern—"especially when one appreciates that the retina itself is a very complex computer." Ronald Burde, an ophthalmologist at Albert Einstein College of Medicine in New York, adds that signal-blocking scar tissue is likely to develop wherever a permanent array touches the ganglion cells. "As a useful human tool a retinal implant is at least a half a century away, if not longer," Burde says.

Because of such doubts, the IOP team has not been able to secure—and the PRI researchers have not even applied for—large-scale government funding from sources such as NIH. As a result, all the retinal implant researchers are working with limited budgets drawn mostly from private backers, such as the Lions Club, the Research to Prevent Blindness Foundation, and the Seaver Institute of Los Angeles, which specializes in supporting selected high-risk scientific projects. And while all agree that success is a long shot, the implant developers insist that it's not quite as long as doubters suppose. Says Rizzo, "It's our job to do our work well and to show the skeptics that there's reason to reconsider."

–Wade Roush

TOXICOLOGY

Dioxin Receptor Knocked Out

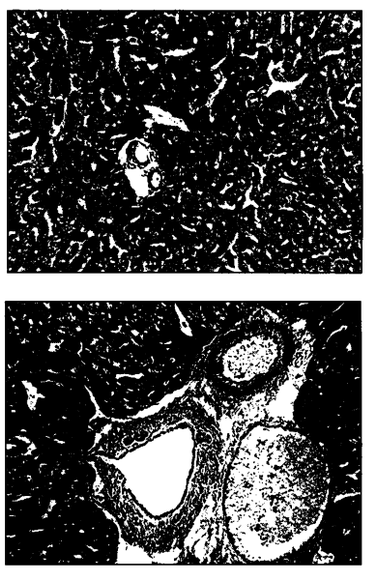
Everybody knows about the immune system for defending the body against infections. But what's less well known is that the body has another defense system: against toxic chemicals. A key feature of this chemical defense is a protein called the aryl hydrocarbon (Ah) receptor that helps detoxify a host of poisons, including polycyclic aromatic hydrocarbons, byproducts of combustion.

New results suggest that this defender protein plays a bigger role in the body than previously thought, perhaps by helping the liver and the immune system develop properly. Not only that, the findings appears to provide an insight into the workings of dioxin, a notorious pollutant that appears to exert its toxic effects, which include cancer and low sperm counts, by binding to the receptor. Indeed, any data shedding light on dioxin's modus operandi will come in handy at the Environmental Protection Agency (EPA), which is now re-evaluating dioxin's health risks to humans. "It's very exciting," says EPA's Linda Birnbaum, a dioxin toxicologist. "The mice will afford us a tool we haven't previously had."

The key to the new findings is a technique that is becoming increasingly important in molecular biology: the creation of knockout mice. On page 722, Frank Gonzalez, Pedro Fernandez-Salguero, and their colleagues at the National Cancer Institute report that they've produced mice lacking the Ah receptor by knocking out the gene encoding the receptor protein.

As soon as the first knockout mice were born, it became apparent that they were abnormal. About half the animals die within a week after birth, apparently succumbing to opportunistic infections that "they just don't have enough lymphocytes [a type of immune cell] to fight off," says Gonzalez. Those that do survive develop massive liver scars and only slowly build up near normal numbers of lymphocytes. Around 10 weeks of age, however, the animals again begin losing those cells and grow sickly, apparently from decreased immune function and liver problems. These effects suggest that the Ah receptor is vital to liver and immune system development and perhaps is "important in pathways crucial for survival," says Stanford University molecular pharmacologist James Whitlock.

Gonzalez suggests that the liver damage occurs because loss of the Ah re-



PHOTOS COURTESY OF JERROLD WARD

Knockout punch. Liver from mouse lacking the Ah receptor is heavily scarred *(bottom)*. A normal mouse liver is shown at top.