plating during the Cambrian explosion as a response to the new-found ability of animals to prey on one another.

Not content to leave the explanation to biologists, paleomagnetician Joseph Kirschvink of the California Institute of Technology has proposed a tectonic driving force for the Cambrian explosion. He sees evidence in the paleomagnetic and geologic records for a thorough reorganization of Earth's crustal motions about the time of the explosion. That redistribution of mass in turn seems to have caused Earth's outer shell of tectonic plates to slip as a unit around the planet's insides, Kirschvink says, like the crust of a hot roasted marshmallow. The geologically sudden shifts of latitude and climate that resulted could have driven an evolutionary leap. Whether it was an arms race among emerging new predators and prey or a slip-sliding Earth, the cause of the Cambrian explosion—when it's finally pinned down—is likely to be as startling as the event itself.

–Richard A. Kerr

MICROSCOPY

Light Microscopes Get a Sharper Look

In modern biology, light microscopes have largely gone by the board, replaced by elaborate imaging machines that depend on electrons, or positrons, or other exotic means of making images rather than plain old light. But light microscopy could be making a comeback. A team of Berkeley scientists has added a laser to an optical microscope, bounced the light off samples, and produced images with such remarkable vertical resolution that they might interest a new generation of researchers in the virtues of light.

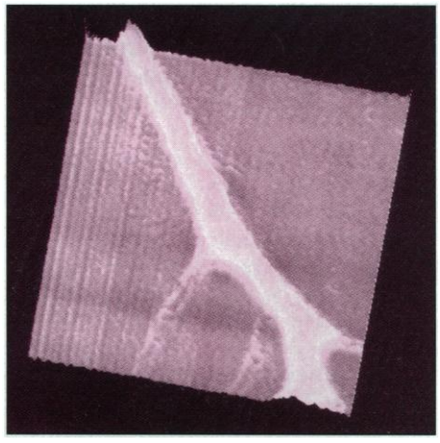
The new instrument, the laser feedback microscope (LFM), was introduced at the annual meeting of the Microscopy Society of America (MSA) in Cincinnati last month by Berkeley biophysicist Alan Bearden, who, with his then-graduate student, Michael O'Neill, and several other colleagues, invented the device. The LFM's superb vertical resolution—capable of measuring a mere 100 Angstroms, or 10 nanometers—met with high approval. "That's very sensitive to depth, something the scanning electron microscope can't detect," says microscopist Steven Pennycook of Oak Ridge National Labs in Tennessee. "It's great for measuring precise heights along the surface of a sample." The horizontal resolution of the images, however, leaves the machine's inventors unsatisfied—and standard microscopy theory holds that it won't be easy to improve.

Nevertheless, unlike electron microscopes, the LFM can examine live cells or other objects without damaging them. As an added bonus, the machine is relatively inexpensive, with an estimated cost of $50,000—compared to over $100,000 for a typical scanning electron microscope. The University of California is currently looking for licensing partners to build the machines.

That imaging systems based on light are making a comeback is something of a surprise, since optical microscopes fell into disfavor years ago because they weren't up to analyzing the minute intracellular structures researchers are interested in. The resolution of an image is inversely proportional to the wavelength used to make it, and the wavelengths of light were too long, resulting in fuzzy pictures. But electron microscopes, though they could give detail on structures as small as viruses, have drawbacks of their own. They require carefully prepared, vacuum-packed samples, eliminating the chance to examine a live cell. Moreover, the hail of electrons they produce can damage delicate samples.

The LFM, in contrast, is an optical instrument based on confocal microscopy—a microscope that bounces light off a single point and back through a tiny pinhole, thus getting improved focus on a single point at a time. This technique brought the optical microscope resolution up to 5000 Angstroms. But the Berkeley team realized they could do better—by changing the way they used the light.

Instead of using light to make images—limited, of course, by that irreducible wavelength—they use laser light as a measuring stick to probe the height differences between adjacent points along the surface of a sample. The process works like this: The microscope sends a laser beam through a pinhole to a precise point on a sample, where it then reflects back up through the hole. Light waves from the original beam and its reflection come together—either becoming brighter, canceling each other out, or a result in between, depending on how far the reflected beam has traveled. The degree of brightness thus indicates the height of the point on the sample. The microscope repeats this process on the next point, and then the next one, eventually feeding all these coordinates into a computer, which creates a precise drawing of every hill and valley on the sample.



Focus like a laser. This image of a chick embryo neuron, originally 40 × 40 micrometers, was produced by a laser feedback microscope.

The direct reflected light the LFM analyzes is a tiny amount—often as little as one-millionth of the original beam. That's why using the laser beam, instead of regular light, is so important. Since the makeup of a laser beam is so specific—comprised of only one wavelength of light—it can only interact with itself, so extra background light can't affect its brightness, explains Berkeley graduate student Terry Wong, who built the most recent version of the LFM. Letting a laser beam bounce back into itself had been considered taboo by most physicists who use lasers, since the beam's brightness can vascillate wildly with the tiniest impetus. But the Berkeley team realized those changes were precisely the variations in brightness that they were looking for.

Once they fitted a laser to their microscope, the team was amazed at the resulting detail. One hundred Angstroms high is only $1/60$ of a light wavelength—and 30 times better than a standard electron microscope. The new instrument is no slouch in the horizontal plane, either. The microscope can reveal details 200 nanometers—which is only slightly larger than those seen by a scanning electron microscope and twice as good as other confocal light microscopes. And, of course, the LFM doesn't damage what it looks at.

As the resolution has gone up, the price has gone down. "There's a cheapo laser and a photodetector and a couple of lenses and a computer and that's it," says Bearden. The relatively low price has already made the device attractive enough so that Ultrapointe Corp. of San Jose, California, has purchased an exclusive license for semiconductor applications.

While the microscope users in Cincinnati seemed quite impressed with the LFM, Bearden isn't satisfied with the horizontal resolution. Some researchers, however, think he doesn't have much choice, since standard microscopy theory holds that it's not possible to improve it. "Examining the latitude is always going to be limited by the wavelength of light," says Pennycook, simply because one can't manipulate the width of a beam the way that you can manipulate the distance it travels. But Bearden is convinced that he can circumvent what he says are misunderstood theories. And while it looks like a long shot, he's been pretty creative so far.

–Karen Fox