rhodopsins had nudged their peak absorbencies to the shorter wavelengths, Yokoyama and his colleagues compared the sequences of the coelacanth rhodopsins to those of other fish that live closer to the ocean surface. They found two amino acid changes in each of the two coelacanth rhodopsins that seemed likely to underlie the shift in wavelength absorbencies.

The researchers went on to test their prediction by introducing mutations into the coelacanth rhodopsin genes to change those amino acids, one at a time, to those found in the typical fish rhodopsin. Measurement of the wavelength sensitivities of the normal and altered coelacanth rhodopsins told the researchers that their predictions were correct. Each mutation contributed additively to shifting the coelacanth opsins from their native sensitivity peaks—a wavelength of 485 nanometers for one and 478 nanometers for the other—to longer wavelengths. The coelacanth's distinctive amino acids apparently alter the fit between the opsin and the chromophore, which starts to vibrate when hit by light, and therefore affect the chromophore's responsiveness to particular wavelengths. Together, Yokoyama says, the amino acid changes enable the coelacanth "to see the limited range of color available in that environment."

After comparing the rhodopsin genes in coelacanths and other fish with the same genes in birds and reptiles, Yokoyama thinks that one of the changes in one gene occurred after coelacanths and other fish went their separate evolutionary ways but before coelacanths and legged animals split up. That same change—replacement of a glutamic acid by a glutamine—occurred independently in the second gene after the coelacanth diverged from this ancestor. Each coelacanth rhodopsin then underwent a second change; in one case an alanine became a serine and in the other, a methionine became a leucine.

More recently, Yokoyama and his graduate student F. Bernhard Radlwimmer have laid the groundwork for more studies of how various opsins have specialized in the course of evolution. Previous work by Yokoyama and others pointed to five sites in the opsins where amino acid changes affect the absorbencies of the so-called red and green pigments used to detect middle wavelengths. He and Radlwimmer have now cloned and sequenced the genes for those opsins in the cat, horse, gray squirrel, white-tailed deer, and guinea pig and, based on which amino acids they contain at those sites, estimated the light-sensing properties of each protein.

Yokoyama and Radlwimmer then made the pigments in cultured cells and tested their predictions. "The additive effects of these amino acid changes fully explain virtually all the [peak light-absorption] values," says Yokoyama. "We can predict what kind of vision [an animal] will have based on the [amino acids] at these five sites." Indeed, says Hiroshi Akashi, an evolutionary biologist at the University of Kansas, Lawrence, "[the] work beautifully demonstrates that a few sites within proteins can account for most differences in the wavelength absorbence in visual pigments." (These results will appear this fall in *Genetics*.) At this point, however, it's less clear how these changes improve each species' ability to see in its particular environment.

For years, Dean says, too many evolutionary biologists have used gene sequence differences simply to assess the evolutionary distance between species, rather than trying to tie them to function. But Yokoyama, he notes, is in a small band of researchers who have taken the next step and begun to study evolution's course from a molecular perspective as well. Dean hopes the approach will spread, because tracing adaptation to molecular changes "allows evolutionary hypotheses to be tested far more rigorously than had been imagined."

—ELIZABETH PENNISI

IMPACT HAZARDS

And Now, the Asteroid Forecast ...

Astronomers have devised a scale to rate the danger posed by asteroids headed for Earth, comparable to the Richter scale of earthquake fame. The so-called Torino scale, which ranges from 0 (no collision) to 10 (certain collision causing Earth-wide devastation), was developed by Richard Binzel of the Massachusetts Institute of Technology and presented to colleagues during a June workshop in Turin (Torino), Italy. The International Astronomical Union endorsed it last week.

The topic of asteroids is "prone to sensationalism," says Binzel. Twice in recent years media hype erupted after astronomers discovered a rock that had a remote possibility of slamming into Earth (*Science*, 20 March 1998, p. 1843, and 23 April 1999, p. 565). "It's very hard to communicate extremely low probabilities to the general public," says Binzel. "The new scale gives us a common lexicon."

The scale, which Binzel had been working on since 1994, takes into account the chances that an asteroid will hit as well as its size and speed relative to Earth. Torino scale values of 8, 9, and 10 refer to certain collisions, with local, regional, and global consequences, respectively. But "the average citizen shouldn't be concerned about an asteroid with a Torino value of 1," says Binzel. The two recently discovered asteroids both would have been rated 1 when they were first discovered, but subsequent observations would have placed them firmly in the 0 category. Binzel says he was advised by science writers Kelly Beatty of *Sky & Telescope* and David Chandler of *The Boston Globe*. "In formulating the scale, we tried to be sociologists as well as scientists," he says.

THE TORINO SCALE

Assessing Asteroid and Comet Impact Hazard Predictions in the 21st Century

Events Having No Likely Consequences	0	The likelihood of a collision is zero, or well below the chance that a random object of the same size will strike Earth within the next few decades. This designation also applies to any small object that, in the event of a collision, is unlikely to reach Earth's surface intact.
Events Meriting Careful Monitoring	1	The chance of collision is extremely unlikely, about the same as a random object of the same size striking Earth within the next few decades.
	2	A somewhat close, but not unusual encounter. Collision is very unlikely.
Events Meriting Concern	3	A close encounter, with 1% or greater chance of a collision capable of causing localized destruction.
	4	A close encounter, with 1% or greater chance of a collision capable of causing regional devastation.
Threatening Events	5	A close encounter, with a significant threat of a collision capable of causing regional devastation.
	6	A close encounter, with a significant threat of a collision capable of causing a global catastrophe.
	7	A close encounter, with an extremely significant threat of a collision capable of causing a global catastrophe.
Certain Collisions	8	A collision capable of causing localized destruction. Such events occur somewhere on Earth between once per 50 years and once per 1000 years.
	9	A collision capable of causing regional devastation. Such events occur between once per 1000 years and once per 100,000 years.
	10	A collision capable of causing a global climatic catastrophe. Such events occur once per 100,000 years, or less often.

CREDIT: R. BINZEL

Carl Pilcher of NASA's Office of Space Science calls the Torino scale "a major advance in our ability to explain the hazard posed by a particular [object]." But will astronomers adopt the new scale? "This will have to sink in a little bit," says Tom Gehrels of the Lunar and Planetary Laboratory of the University of Arizona, who heads one of the projects searching for near-Earth objects. But he adds, "I think we ought to use it."

—GOVERT SCHILLING

Govert Schilling is a writer in the Netherlands.