are lasting effects." Adds Plotsky, "you can do something fairly mundane in the first days of the animal's life, and somehow this changes how that animal responds to its environment for the rest of its life."

Tracing temperament

But it's not only environmental effects—both extreme and subtle—that color emotional responses. Studies in both animals and humans support the idea that individuals carry certain dispositions throughout their lives. For example, Kalin has found that some infant monkeys are abnormally fearful, exhibiting a startled "freeze" behavior with very little provocation and having high baseline cortisol levels. And in humans, decades of study by Harvard University psychologist Jerome Kagan and his colleagues are revealing what look like innate, lifelong temperaments. Kagan's group examined 450 baby boys and girls, first at 16 weeks, then again at 14 months, 21 months, 4 years, and 7 years, by testing their response to cues they could see, hear, and smell, such as a cotton swab dipped in alcohol.

They found that 20% of the 16-week-old infants fell into a test category Kagan calls "high reactive": The tests made them fretful and agitated. Another 35% responded with little distress and low motor activity. Over time, some of the high reactives began to respond normally, while others began to show extreme shyness. None became a bold, fearless child, says Kagan. By age 7, about one-third of the high reactives had developed extreme fears compared with 10% of the others, Kagan said at the NIMH meeting.

Brain imaging complements these behavioral studies by showing a consistent package of brain activation that dovetails with temperamental differences. In Kalin's study, the abnormally fearful rhesus monkeys also had relatively more right frontal brain activity, as recorded by electroencephalograms.

Davidson finds a similar asymmetry in people. People who are negative or depressed according to standardized psychological tests tend to show more baseline prefrontal activity on the right, he says. And the happy-go-lucky folks who are more likely to bounce back when life throws a curve ball tend to show more activity in the left prefrontal cortex.

He speculates that the prefrontal cortex modulates the emotional activity of the amygdala. People with more left prefrontal cortex activity can shut off the response to negative stimuli more quickly, he says. "Being able to shut off negative emotion once it's turned on is a skill that goes with left activation." He adds that it's not yet known whether such temperaments are inborn or a product of very early life experiences.

Indeed, Davidson and others caution that they have far to go in explaining the full biological basis of our passions. LeDoux calls the state of the science of emotions "infantile," as the only emotion for which the neural hardware and software is well understood is fear, and even that has mostly been parsed in the rat. "Things have not entirely coalesced into a coherent picture," agrees NIMH director Steve Hyman. He hopes to help it develop, by pushing neuroimagers to test hypotheses about the neural circuits, and by "goosing cognitive neuroscience to start considering emotion." Darwin would no doubt approve and sympathize. Understanding the origin of emotional expressions remains a great difficulty, he wrote, and "it deserves still further attention."

–Christine Mlot

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PALEONTOLOGY

Biggest Extinction Looks Catastrophic

The most profound ecological disaster in the history of the planet struck at the end of the Permian period 250 million years ago, snuffing out about 85% of the species living in the ocean and 70% of the vertebrate genera on land. But devastating as this event was, until recently most paleontologists believed that the dying was long and slow, lasting 8 million years or more. And most looked to such causes as gradual sea level fall and climate change. Then last year new dates from Chinese rocks shrank the final pulse of marine extinctions to less than 1 million years (*Science*, 7 November 1997, p. 1017). Now more dating of the same rocks squeezes the disaster even further—and suggests a catastrophic cause, perhaps even a comet or asteroid impact.

D. ERWIN / NMNH / SMITHSONIAN INSTITUTION

End of an era. Late Permian rock (light band) records an isotopic shift.

The new results, reported on page 1039, show that a shift in the ratio of carbon isotopes recorded in marine rocks—an event intimately tied to the extinctions—lasted perhaps as little as 10,000 years. "It's the final nail in the coffin of those who say the extinction was prolonged," says paleontologist Paul Wignall of the University of Leeds in the United Kingdom.

The telltale rocks, near the village of Meishan in southern China, are beds of ancient marine sediments that record the disappearance of marine animals and, at the same time, a huge spike in the ratio of carbon-13 to carbon-12. The isotopes, taken from the rock itself, offer a more continuous record than fossils, which are subject to the vagaries of preservation. So geochronologist Samuel Bowring of the Massachusetts Institute of Technology, paleontologist Douglas Erwin of the National Museum of Natural History in Washington, D.C., paleontologist Jin Yugan of the Nanjing Institute of Geology and Paleontology in China, and their colleagues applied a well-established dating technique—based on the clocklike radioactive decay of uranium to lead—to volcanic ash layers scattered through the rock beds. The team's dates showed that the isotopic drop and a partial recovery took 165,000 years at most, and possibly as few as 10,000 years.

Such a dramatic, rapid shift in oceanic carbon isotopes requires an equally dramatic explanation—perhaps that the microscopic plants that maintain a normal carbon isotopic ratio in the ocean were suddenly nearly wiped out, say Bowring and colleagues. That makes falling sea level, for example, an unlikely driving force, notes Erwin.

The researchers speculate that the ultimate culprit was volcanism—the massive eruption of the Siberian Traps, which began at or within a few hundred thousand years of the boundary and ended in less than a million years. The global haze of sulfur particles from the eruption—the largest ever on land—may have caused a sudden chill by reflecting sunlight, or massive carbon dioxide emissions might have led to prolonged greenhouse warming, the team speculates. Or perhaps these direct volcanic effects induced indirect effects, such as a sudden overturning of the ocean, that both killed off species and triggered the isotopic spike.

It's even possible that a huge impact was the culprit, say Bowring and Erwin. If the impactor was a comet, its considerable load of organic material, which would have contained isotopically light carbon, might have directly produced the spike. For now, the ultimate cause remains a mystery. But "whatever happened," says Erwin, "it happened very quickly."

–Richard A. Kerr