of oil gushing from wells today. In fact, the rate at which any well—or any country—can produce oil always rises to a maximum and then, when about half the oil is gone, begins falling gradually back to zero."

Some of today's larger oil producers, including Norway and the United Kingdom, will, unless they cut back sharply, reach their production peaks in about two years, according to Campbell and Laherrère. Then they will have to reduce output. By about 2002, the world will be dependent on Middle Eastern nations—particularly, Iran, Iraq, Kuwait, Saudi Arabia, and the United Arab Emirates—to satisfy growing demand. That raises the specter of another 1970s-style massive price increase. That would curb demand, leaving prices volatile. "But by 2010 or so, many Middle Eastern nations will themselves be past the midpoint. World production will then have to fall," the two researchers predict. Unless demand for oil shrinks, prices will rise.

"The world is not running out of oil—at least not yet," Campbell and Laherrère explain. "What our society does face, and soon, is the end of the abundant and cheap oil on which all industrial nations depend."

Can anything be done? Yes, say other specialists writing in the same issue of *Scientific American*. Recent technological advances—in tracking the flow of underground crude oil, steering drills horizontally, pressurizing "dead" wells, and tapping oil fields that lie deep underwater—if deployed as planned on the largest oil fields within three to five years, "could lift global oil production rates more than 20 percent by 2010," claims Roger N. Anderson, director of petroleum technology research at Columbia University's Energy Center.

Another, unconventional source of oil is bitumen, "a black, tarlike substance . . . in the pore spaces between the grains of certain sands and shales (solidified muds)," notes Richard L. George, president and CEO of Suncor Energy, a company involved in mining such resources. In Alberta, Canada, alone, he estimates, some 300 billion barrels could be recovered from oil sands—more than the reserves of conventional oil in Saudi Arabia.

Oil is not the only source of energy, of course. There's nuclear fission, solar energy, and wind power, to name a few. Safaa A. Fouda, of CANMET Energy Technology Center, a Canadian government laboratory in Ontario, contends that natural gas holds great promise. It is not only the cleanest of fossil fuels but also one of the most plentiful: analysts estimate that there is enough readily recoverable natural gas in the world to produce 500 billion barrels of synthetic crude oil—more than twice the amount of conventional crude oil ever found in the United States. The challenge, she notes, is finding a cheap way to liquefy it, so that it can be piped to market inexpensively. Even today, she says, natural gas can be converted into liquid fuels at prices that are only about 10 percent higher per barrel than the price of crude oil. With the right process, liquid natural gas could even power cars and trucks that now run on gasoline.

Campbell and Laherrère also look to natural gas as a promising substitute for oil. "With sufficient preparation . . . the transition to the post-oil economy need not be traumatic," they conclude. "If advanced methods of producing liquid fuels from natural gas can be made profitable and scaled up quickly, gas could become the next source of transportation fuel. Safer nuclear power, cheaper renewable energy, and oil conservation programs could all help postpone the inevitable decline of conventional oil."

Bird Theory in Flight

"The Origin of Birds and Their Flight" by Kevin Padian and Luis M. Chiappe, in *Scientific American* (Feb. 1998), 415 Madison Ave., New York, N.Y. 10017–1111;
"The Big Flap" by Larry D. Martin, in *The Sciences* (Mar.–Apr. 1998), New York Academy of Sciences, 2 E. 63rd St., New York, N.Y. 10021.

Is that feathered creature outside your window a dinosaur, or at least a descendant of one? *Yes*, beyond any "reasonable doubt," assert Padian, a professor of integrative biology and curator in the Museum of Paleontology at the University of

California, Berkeley, and Chiappe, a Fellow at the American Museum of Natural History in New York.

The long-running scientific debate over the origin of birds is now over, they claim: paleontologists have determined "that birds descend from ground-dwelling, meat-eating dinosaurs of the group known as theropods." However, Martin, a paleo-ornithologist and curator for vertebrate paleontology at the University of Kansas Natural History Museum, maintains not only that the debate is *not* over but that the bird-dinosaur link has become increasingly dubious.

The controversy began in 1870, when Thomas Henry Huxley, "Darwin's bull-dog," first suggested that theropods and birds were closely related. A century later, Yale University paleontologist John H. Ostrom revived Huxley's idea. After studying the bones of the 150-million-year-old *Archaeopteryx lithographica* (unearthed in Germany in 1861 and considered the oldest known bird specimen), Ostrom explicitly proposed that birds were direct descendants of theropods.

An early depiction of a proto-avian descended from reptiles, as imagined by a Danish paleontologist.

His conclusion has been "strongly validated," Padian and Chiappe say, by cladistics, a new method of analyzing the nature of relationships among organisms. Unlike traditional techniques, which might exclude a species from a group solely because it had a trait not shared by others in the group, cladistics arranges organisms on the basis of whether they have a set of newly emerged heritable traits in common. Cladistic analysis, write Padian and Chiappe, "shows that birds are not only *descended* from dinosaurs, they *are* dinosaurs (and reptiles)—just as humans are mammals, even though people are as different from other mammals as birds are from other reptiles."

The evidence is not confined to shared skeletal features, Padian and Chiappe argue. Recent discoveries of nesting sites in Mongolia and Montana suggest some similar reproductive behaviors. Skeletons of the Cretaceous theropod *Oviraptor* ("egg stealer") recently found atop nests of eggs, for example, indicate that instead of living up to their name, the dinosaurs were protecting the eggs in very birdlike fashion.

But Martin and other investigators are skeptical. "In spite of recent fossil finds that might support a dinosaurian origin for birds," he says, "other new evidence contradicting that view is just as strong, if not stronger." Two studies published in *Science* last fall, he notes, one focusing on lungs and the other on limbs, both argued that dinosaurs are clearly distinct from birds.

Martin himself grew disenchanted with the dinosaurs-to-birds theory after comparing some 85 anatomical features the two vertebrates were said to share. "To my shock, virtually none of the comparisons held up," he writes. The confusion over anatomy is partly due, he believes, to gaps in the ornithological literature about many aspects of the avian skeleton. Dinosaur specialists generally leave avian anatomy to the ornithologists, who usually prefer to study birds' songs, plumage, and behavior rather than their bones and muscles. Existing anatomical knowledge of both dinosaurs and *Archaeopteryx*, meanwhile, is "just blurry enough" to justify bird-dinosaur comparisons of anatomical features that do not precisely match. "When the burden of ad hoc repairs became too heavy for me, I had to abandon the theory altogether," Martin writes. "It was a disappointment. How wonderful it would have been if dinosaurs had escaped extinction!"