fashion. As Ambros asks, "If *lin-14* is controlling the timing of the expression of cell lineages, then what is controlling *lin-14*? What is the clock?"

Another major unanswered question concerns the way in which heterochronic genes might be working. "We don't really have any convincing evidence about how they act," Horvitz says, "but our favorite hypothesis is that these genes function in the way that *Drosophila* homeotic genes are thought to function, namely, by specifying regulatory proteins that are expressed and act within the cells they affect." Another possibility is that the genes control the levels of hormone-like substances that act throughout the animal. Such a mechanism appears to regulate axolotl development. The body tissues of the animal remain immature because it does not produce enough thyroxine, which is needed for metamorphosis to occur.

Mutations in *lin-14* affect many cell lineages and produce widespread alterations in *C. elegans*. It will also be interesting to determine whether the gene acts by controlling the activity of other genes. According to the current view, development is controlled by hierarchies of genes, with those in the higher ranks turning on or off, as the case may be, the more specifically acting genes in the lower ranks. *lin-14* might be one of the higher ranking genes in the *C. elegans* developmental hierarchy.

In contrast to the situation with *lin-14*, the alterations caused by mutations in *lin-29* are much more restricted in scope. They are limited to certain cuticle-forming cells of the fourth larval stage. Genes with such specific effects might then be lower in the hierarchy and under the control of genes, such as *lin-14*, with more diffuse effects.

To determine whether heterochronic mutations might have played a role in nematode evolution, Ambros and Horvitz have begun examining roundworm species that are related to *C. elegans* to see whether their cell lineages show variations in timing analogous to those occurring in the heterochronic mutants just identified. If this turns out to be the case, then the work on heterochronic genes may help provide genetic and molecular explanations not just of the temporal regulation of development but also of a common mechanism of evolution.

—JEAN L. MARX

Additional Reading

1. S. J. Gould, *Ontogeny and Phylogeny* (Belknap, Cambridge, Mass., 1977).
2. R. A. Raff and T. C. Kaufman, *Embryos, Genes, and Evolution* (Macmillan, New York, 1983).
3. M. Chalfie, H. R. Horvitz, J. E. Sulston, *Cell* **24**, 591 (1981).

How Fast Is Oil Running Out?

An expert at the Library of Congress's Congressional Research Service (CRS) has projected a 17 percent decline in U.S. oil production by the year 2000.* That is his optimistic prediction. If discoveries do not pick up soon in the more promising oil provinces, production will drop 29 percent, he says. To those who hold out hope that production might be maintained if only industry is given a fair profit and a free hand, he says they must be wrong.

To test the optimistic hopes for constant production, Joseph Riva, a CRS resource analyst who has searched for oil here and abroad, estimated how much oil would have to be found to maintain the 1982 production level of 2.95 billion barrels per year. That production requires a certain amount of known reserves that can be drawn on. A relatively new oil field can be tapped for about 10 percent of its remaining oil each year (reserves-to-production ratio of 10:1). Pump harder and the field can be ruined, the way sucking too hard on a straw can spoil a milk shake. As a field is depleted, its ratio of reserves to production will drop. Riva assumed that the present domestic ratio of 9:1, which reflects America's already dwindling oil resource base, would drop farther to 8:1 by 1995.

In order to maintain 1982 production under these conditions, the oil industry would have to discover almost 45 billion barrels of oil during the 18 years between 1982 and 2000, according to Riva's calculation. That, he points out, is 70 percent of all the oil left undiscovered in 1982. In comparison, drillers found only 44 percent of the undiscovered oil of the preceding 18 years. And it is harder to find oil now than it was then. Except in Alaska and offshore California, most of the big, easily found fields have been discovered already. To find that much oil in the remaining fields, drillers would have to discover fields six times faster than in the past.

To calculate the seemingly inevitable decline, Riva combined, on a region-by-region basis, present estimates of oil left to be discovered and past performance in finding oil. The estimates of undiscovered oil (and oil to be found by expansion of known fields) are derived from those of the U.S. Geological Survey. In well-explored, mature regions such as West Texas, Riva chose to use the mode of USGS estimates rather than the mean in order to moderate the influence of rare, large finds, unlikely events in such thoroughly drilled areas. Riva's total estimate of undiscovered oil was about 64 billion barrels. He then assumed that drillers would find the same or a larger percentage of undiscovered oil (and field expansion oil) in the next 18 years as they did in the past 18 years. Regions like the Rocky Mountains, where hopes are high that the best finds are yet to come, were assumed to have higher discovery rates than past experience indicated. In this projection enhanced oil recovery—the thinning of oil before pumping—would not increase, contrary to some forecasts of a doubling.

By this calculation, Riva projects a 17 percent drop in production by 2000. All major producing regions would decline except the Rocky Mountains–Northern Great Plains region. Alaska's production would drop 16 percent, West Texas's 40 percent, and the Gulf Coast's 44 percent. Riva considers this 17 percent decline " a very optimistic projection." He and many others consider the USGS estimates of undiscovered oil in the Rocky Mountains, off the Atlantic coast, and perhaps even in Alaska to be overly optimistic, especially in light of recent drilling disappointments (*Science*, 27 January, p. 382). It is certainly optimistic to expect future finds to be as easy as past discoveries, most of the big fields having already been found.

A more likely production decline, Riva says, is 29 percent. That assumes that no oil is found off the Atlantic coast or in the Oregon-Washington region and that things do not improve in the Rocky Mountains–Northern Great Plains region. That decline still assumes an Alaskan discovery rate equal to the one that included the discovery of the supergiant Prudhoe Bay field. A distinct downward trend in U.S. oil production should show up in a few years, says Riva, as field depletion overwhelms the unprecedented drilling of production wells of the past 5 years.—RICHARD A. KERR

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