plan emphasized the creation of chromosome maps, software, and automated technologies to enable sequencing.

By 1993, unexpectedly rapid progress in chromosome mapping required updating the goals [*Science* **262**, 43–46 (October 1, 1993)], which now project through 1998 (see p. 5). This plan is being revised again in anticipation of the approaching high-throughput sequencing phase of the project. Last year marked an early transition to this phase as many more genome sequencing projects were funded. The second and third phases of the project will optimize resources, refine sequencing strategies, and, finally, completely determine the sequence of all base pairs in the genome.

Another area of DOE and NIH cooperation is in exploring the ethical, legal, and social issues (ELSI) arising from increased availability of genetic data and growing genetic-testing capabilities. The two agencies established a joint working group to confront these ELSI challenges and have cosponsored joint projects and workshops.

DOE Genome Program

A general overview follows of recent progress made in the DOE Human Genome Program. Refer to the timeline (pp. ii–iii) for other achievements toward U.S. goals, including contributions made outside DOE.

Physical maps

For DOE, an early goal was to develop chromosome physical maps, which involves reconstructing the order of cloned DNA fragments to represent their specific originating chromosomes. (A set of such cloned fragments is called a library.) Critical to this effort were the libraries of individual human chromosomes

of August 1997. Structural studies are under way to learn what is unique about the proteins of these organisms—the ultimate aim being to use the microbes and their enzymes for such practical purposes as waste control and environmental cleanup.

Biotechnology

The potential for commercial development presents U.S. industry with a wealth of opportunities. Sales of biotechnology products are projected to exceed $20 billion by the year 2000. The genome project already has stimulated significant investment by large corporations and prompted the creation of new biotechnology companies hoping to capitalize on the far-reaching implications of its research.

Energy Sources

Biotechnology, fueled by insights reaped from the genome project, will play a significant role in improving the use of fossil-based resources. Increased energy demands, projected over the next 50 years, require strategies to circumvent the many problems associated with today's dominant energy technologies. Biotechnology promises to help address these needs by providing cleaner means for the bioconversion of raw materials to refined products. In addition, there is the possibility of developing entirely new biomass-based energy sources. Having the genomic sequence of the methane-producing microorganism *Methanococcus jannaschii*, for example, will enable researchers to explore the process of methanogenesis in more detail and could lead to cheaper production of fuel-grade methane.

Risk Assessment

Understanding the human genome will have an enormous impact on the ability to assess risks posed to individuals by environmental exposure to toxic agents. Scientists know that genetic differences make some people more susceptible—and others more resistant—to such agents. Far more work must be done to determine the genetic basis of such variability. This knowledge will directly address DOE's long-term mission to understand the effects of low-level exposures to radiation and other energy-related agents, especially in terms of cancer risk.