tists continue to lead the U.S. effort. Although "production sequencing" of the human genome is just beginning around the world, the project has already produced newsworthy results. Los Alamos and Livermore have published high-resolution maps of chromosomes 16 and 19, the first efforts to provide a sufficient number of chromosomal signposts to support large-scale sequencing projects. In the process of this and later work, mappers uncovered genes implicated in many human ailments, including adult-onset diabetes, pathologically high cholesterol levels, the most common form of muscular dystrophy (a success shared by an international team of researchers), and very recently, Down's syndrome. Livermore also shares credit for founding the I.M.A.G.E. (Integrated Molecular Analysis of Genomes and their Expression) Consortium, which coordinates the world's largest public collection of cloned gene fragments, an invaluable resource for the international biological community. Berkeley, meantime, has focused on automating a large-scale sequencing technology, which has been adopted by private companies and by two major NIH sequencing efforts.

Another part of the task is genome "informatics," the full range of computational support the project demands. At Oak Ridge, for example, researchers in 1991 developed GRAIL (Gene Recognition and Analysis Internet Link), an on-line computer program that uses the principles of artificial intelligence to sort out genes from the much longer stretches of noncoding DNA in the genome. In 1995 alone, the international community used GRAIL to search for genes among 180 million base pairs of human DNA—a volume of DNA equal to six percent of the entire genome. OBER also manages the world's central repository of mapping information, the Genome Data Base at the Johns Hopkins University.

The OBER genome program also broaches ethical, legal, and social issues. For example, one effort has led to high school curriculum units on human genetics and on the ethical management of genomic information. In addition, a model privacy act developed at Boston University's School of Public Health has become the basis for pending state and federal legislation aimed at safeguarding individual rights. And yet another effort, headed by the nonprofit Einstein Institute for Science, Health and the Courts, led to educational workshops for state and federal judges who must deal with increasingly sophisticated genetic evidence.

THE THREADS OF LIFE

■ In the fifties and sixties, the details of the genetic apparatus were still being filled in: the double helix discovered, the genetic code deciphered, and the intricate process of protein synthesis sorted out. In 1956 Oak Ridge scientists Larry Astrachan and Elliot Volkin isolated a form of RNA that they called "DNA-like RNA." Four years later, this molecule would become known as messenger RNA (mRNA), the molecular courier that carries the instructions contained in DNA to sites where the encoded information is used to produce enzymes, antibodies, and the rest of the body's proteins. Among the visual landmarks of this period were early images from Brookhaven showing RNA to be made in the nucleus of the animal cell and then the first photo (below) of mRNA actually being transcribed from chromosomal DNA. This picture, a high-resolution electron microscope image, was produced at Oak Ridge in 1970. ■

1979 High levels of naturally occurring radon were observed by Argonne researchers in homes in the Midwest, a consequence of soil porosity beneath the houses, rather than the concentration of radium (the parent of radon) in the soil. Public awareness of radon would be heightened in the mid-eighties, leading to an intensive national research program.

1982 Brookhaven scientists William Studier and John Dunn completed the first DNA sequence of a double-stranded virus, the bacteriophage T7. At 39,936 base pairs, it was the longest sequence then known.

1984 The National Laboratory Gene Library Project was established jointly between Livermore and Los Alamos to create chromosome-specific gene libraries from each of the human chromosomes and to distribute them to the worldwide scientific community.