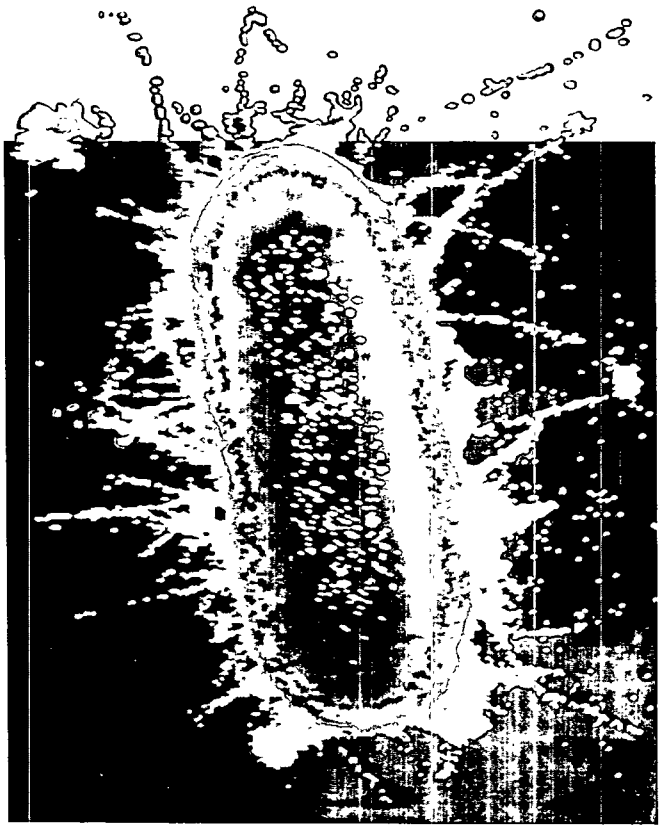


Genetic techniques to stabilize recombinant microorganisms, such as E. Coli *bacterium, could provide the basis for efficient, economical, large-scale bioproduction of chemicals and fuels.* (Photo by J. A. Engler, T. R. Broker, and J. I. Garrels. Reprinted with permission from *Molecular Cloning: A Laboratory Manual*, 1982, Cold Spring Harbor Laboratory.)

of consumed energy, with an estimated payback period of 3.7 years. It is estimated that the process can save approximately 10% to 20% of the 1.89 quads of energy used annually in process drying applications.

Genetic Engineering for Efficient Biochemical Processes

The application of genetic engineering to certain microorganisms should lead to greatly reduced production costs for some organic chemicals. Microorganisms can be grown on relatively inexpensive feedstocks, such as biomass. Production costs for some organic chemicals will be lower if genetically engineered processes can be scaled up. Yet, before this potential can be realized in large-scale industrial processes, a method must be developed for stabilizing and retaining genetically engineered traits in large quantities (cultures) of microorganisms.

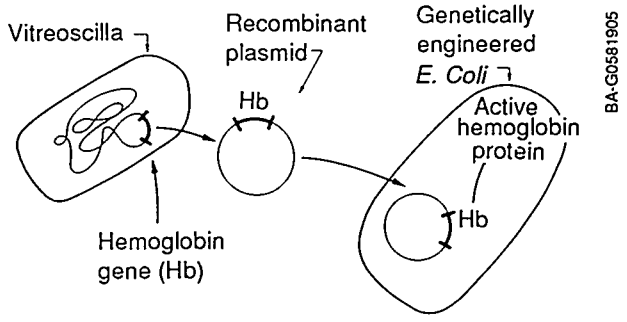
In response to this need, DOE developed a new method of gene cloning and amplification that will be far superior to the standard method in supplying stable strains of microorganisms for large-scale applications. In the new method, foreign genes or genes of interest carried on a plasmid are introduced directly into the main chromosome of the microorganism. In one experiment, for example, a specific gene of interest was inserted into the bacteriophage *E. coli* and was subsequently observed to be amplified.

This process will lead to improved stability and productivity of recombinant DNA microorganisms. In addition to the potential for aiding in large-scale chemical production by biocatalysis, this research should also be applicable to the production of pharmaceuticals and biological materials.

Efficient Aerobic Fermentation

Biocatalysts can facilitate desired chemical reactions in one step by lowering the activation energy barrier. Unfortunately, the availability of oxygen necessary for microorganisms is a major constraint in the growth and production of microorganisms within the bioreactor used in aerobic fermentation. Biochemical engineers devised a variety of bioreactor geometry and stirrer configurations to minimize this problem. But now, under DOE sponsorship, a breakthrough technology with broad application has been developed for aerobic fermentation using genetically engineered microorganisms.

Researchers at the California Institute of Technology have shown that the oxygen limitation problem can be minimized by genetically inserting a hemoglobin gene into *E. coli* bacteria. It was clearly demonstrated that *E. coli*-possessing plasmids containing



By implanting a hemoglobin gene in an E. Coli *bacterium, researchers can improve the growth and productivity of genetically engineered aerobic microorganisms.*