now developing maps of the positions of the two types of fragments (those produced by endonuclease R and those produced by endonuclease Z) in the ϕX174 genome.

Edgell and Hutchison want to use the mapped fragments to locate interesting regions—sites of initiation or termination of RNA synthesis, for example—that are difficult or impossible to map by conventional genetic techniques. They now think that they have identified three promoter regions. (The promoter is the DNA region that binds RNA polymerase, the enzyme that catalyzes RNA synthesis.) One promoter appears to be located within a segment of the ϕX174 genome about 100 nucleotides long. It should be possible to sequence a DNA fragment of that size. Moreover, according to Edgell and Hutchison, simultaneous treatment of ϕX174 RF with both endonucleases R and Z should produce that fragment.

Eukaryotic chromosomes, because of their greater size and complexity, are much more difficult to study than the relatively simple viral chromosomes. However, several scientists are beginning to use bacterial restriction enzymes to probe the structure of these chromosomes. For example, Charles Thomas at Harvard Medical School, Boston, has been investigating the structure of the lampbrush chromosomes of newt oocytes (developing egg cells). These chromosomes have loops of temporarily unwound DNA projecting from them. Thomas finds that the enzyme from *H. influenzae* breaks some, but not all, of the loops. The patterns of breakage and the size distribution of the DNA fragments produced should give some information about gene arrangement in the chromosomes. It is also theoretically possible to isolate particular genes by cleaving chromosomes with the right combination of restriction enzymes.

The ability to isolate and combine DNA's from two or more different sources permits a new approach for studying control of gene expression. Endonucleases RI and RII, because they generate cohesive ends, should be particularly useful for the production of such combined DNA molecules. Boyer and his colleagues plan to use these enzymes to insert bacterial or even mammalian DNA into bacterial plasmids. The plasmids would then serve to introduce this new DNA into bacterial cells, where its expression could be studied.

Speaking of Science

Holography: Beginnings of a New Art Form

Paintings, statues, and many other art works are appreciated because of nuances of shape and color discernible by the human eye. Visual appeal is also the basis of most advertising and commercial displays. Not surprisingly, then, advances in optical science have found reflections in both pure and commercial art. Photography, for example, made possible a much wider acquaintance with the limited supply of ancient art treasures, and became a new art form in itself. Television provided a new advertising medium whose potential for viewer involvement is much higher than that of the printed page.

The most recent advances in optical science—lasers and the holographic techniques that they make possible—are still largely confined to industrial and university laboratories. But their potential for creating new visual forms and for enhancing our perception of old forms has not gone unnoticed. Indeed, because holographic images are three-dimensional and can be projected so as to appear free-standing, they have more dramatic possibilities than any two-dimensional medium. And recently, with development of high-powered lasers and pulsed-laser holography, the first tentative invasions of the commercial marketplace and of the art world have begun.

One of the more striking commercial displays is the image of a hand offering a diamond ring and bracelet (shown at left), which was suspended above the sidewalk on Fifth Avenue in New York during November 1972, stopping traffic and attracting attention to Cartier's, from whose front window the hand seemed to protrude. The image, which provoked one passerby to assail it with her umbrella and declare it to be "devil's work," was projected from a hologram produced by Holoconcepts Corporation of America and McDonnell Douglas Electronics Company. Holoconcepts is one of several firms now using holography to create promotional displays, and according to its president, Robert Schinella, this medium makes possible "a new world of selling and marketing products."

Making holograms of life-size objects requires powerful lasers to illuminate them. McDonnell Douglas Electronics, for example, uses a 10-joule ruby laser to record holograms of objects as large as 3 by 3 by 2½ meters. Moreover, the coherence length of the light must be as great as the depth of the object or scene. Only in the last few years have lasers whose emissions have coherence lengths of several meters been developed by R. Wuerker and his colleagues at TRW in Redondo Beach, California, and others. Light pulses of very short duration have also been achieved, making possible holographic "snapshots" of living subjects. A firm that is now part of McDonnell Douglas Electronics, for example, made a holographic portrait of Dennis Gabor, the inventor of holography, who in 1971 was awarded the Nobel Prize in Physics for his work. More recently, Salvador Dali has reportedly created a three-dimensional portrait of the controversial rock star Alice Cooper in what is perhaps the first use of the holographic medium by a well-known artist.

Because of the three-dimensional nature of holography, this technique would seem a natural for preserving copies of decaying statuary. This idea, which curiously enough arose out of a 1971 summer study of lasers and their economic implications by the Jason group of scientists, led Walter Munk of the University of California

Another way to introduce new, functional DNA into cells—mammalian cells in this case—is to combine it with the genome of a transforming virus like SV40. Paul Berg and his colleagues have achieved just that; they were able to insert the *E. coli* galactose operon—the gene sequence required for galactose metabolism—into the SV40 chromosome. They used endonuclease RI to open both the circular SV40 DNA molecule and also a circular plasmid carrying the galactose operon. They then generated cohesive ends on these linear molecules by enzymatically adding a chain of adenine nucleotides to the 3′ ends of the SV40 DNA and a chain of thymine nucleotides to the 3′ ends of the DNA containing the galactose operon. (This step ensures that the two different molecules will combine.) Mixture of the two molecules, followed by appropriate enzyme treatment to complete and covalently join them together, yields a new circular molecule containing both sets of genes.

The next step is to transform cells with these molecules. The enzymes of *E. coli* and of mammalian cells are probably sufficiently different to be distinguishable. Thus, if the *E. coli* galactose genes function in the transformed cells, this should be a good system for studying the regulation in mammalian cells of a gene system whose function in *E. coli* is reasonally well understood.

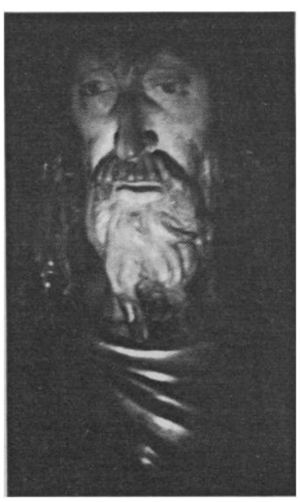
The ability to introduce functioning genes into mammalian cells has obvious implications for genetic engineering. At present, however, Berg emphasizes that his main interest is the study of gene regulation in mammalian cell cultures. He believes that the prospect of gene replacement therapy by this mechanism is remote and fraught with difficulty. An oncogenic virus, like SV40, is not an appropriate vehicle for introducing new genetic material into the cells of living organisms. Moreover, he thinks that it will be most difficult to design a gene carrier that will produce only the desired effect without also causing harmful side effects. Nevertheless, the prospect of such genetic modification, however distant and remote, exists.—JEAN L. MARX

Additional Readings

1. K. Danna and D. Nathans, *Proc. Nat. Acad. Sci. U.S.A.* **68**, 2193 (1971).
2. D. A. Jackson, R. H. Symons, P. Berg, *ibid.* **69**, 2904 (1972).
3. M. Meselson, R. Yuan, J. Heywood, *Annu. Rev. Biochem.* **41**, 447 (1972).
4. M. Sclair, M. H. Edgell, C. A. Hutchison, III, *J. Virol.* **11**, 378 (1973).

or At Least of an Advertising Bonanza

at San Diego (UCSD) to propose a series of experiments that were carried out by John Asmus of Science Applications Incorporated in Albuquerque, New Mexico, and Wuerker from TRW. Working in cooperation with F. Valcanover, superintendent of galleries in Venice, Italy, they successfully produced holograms of several Venetian statues (see photograph of the holographic image of a 15th-century woodcarving of St. John the Baptist by Donatello, at left). According to Asmus, these first holograms were crude but nonetheless produced images that were esthetically satisfying to see. Potentially, holograms could be used to build an archival library of the world's statuary, storing information that could someday be used to reproduce damaged objects. Since 35 percent of Venetian art is now severely damaged, according to Valcanover, and that in many other cities showing decay as well, the matter is of no little urgency.



The Venice experiment also yielded a hopeful means of reversing the decay of art works. More or less by accident, the investigators found that a laser beam is an excellent way to clean marble surfaces blackened by weathering and air pollution. Since then, Asmus has experimented with other artifacts—from stained manuscripts to encrusted bronzes—and finds that by varying the pulse length and energy of his laser he can clean nearly anything; he is consequently being deluged with requests from art restoration centers around the world.

Reproduction of art objects is an unpopular concept among artists and those who believe that pirated copies will diminish the value of the original, and that aspect of holographic copying of statues has yet to be faced. Nonetheless, according to Munk, holographic images would preserve for posterity many pieces of art that are now rapidly decaying under the combined onslaughts of weather, corrosive organic pollutants, and acts of vandalism, such as the damaging of the "Pietà"—in effect, the holograms would serve as a uniquely accurate template for reproduction or repair. Comparisons of two holograms taken in rapid succession gives an interference pattern that can identify points of stress, submicroscopic cracks, and other information that would aid in restoration. To investigate these and other possibilities, a new institute for science in art is in the process of being formed at UCSD.

Only a few artists are actively doing holographic art, and in some quarters the medium is receiving the sneers that originally greeted computer-generated music. Means of physically reproducing art forms in ways that can take advantage of the accuracy of the information stored in a hologram are not yet available, so that copies of statuary are not an immediate prospect. But holographic images of statues could be displayed, making these art objects accessible to a far greater audience and thus perhaps helping to alleviate the conflict between the need for greater physical security in museums and the desire to allow more people to enjoy their contents. Nonetheless, any major impact of holographic techniques on the art world, which is more conservative in its acceptance of new techniques than the commercial art community, seems to be some time off. But look for bolder, brighter, three-dimensional advertisements in the near future.—ALLEN L. HAMMOND