

# JPL Looks at Inner Space

Image-processing equipment, developed at Caltech's Jet Propulsion Laboratory to enhance planetary photographs radioed back from spacecraft, has now been converted to an experimental system that can speed up by a factor of ten the analysis of pictures of human chromosomes.

Chromosomes are the tiny bodies that contain the basic patterns for life—the genes. Seen through a microscope, they appear to resemble a tangle of short spaghetti strands or stubby worms. Each chromosome contains strings of DNA molecules, which are believed to be the reproductive basis of all living organisms. DNA—deoxyribonucleic acid—holds the key to the genetic code of life on earth.

Chromosome analysis, or karyotyping, is a valuable medical tool, but it sees limited use at present because it is so time-consuming and expensive. (Karyo is the biological term for the nucleus of a cell.) As a result of JPL's experiments such analysis may become more widely used. When this happens, it will greatly aid the process of determining the genetic effects of atomic radiation, drugs (such as thalidomide and LSD), and environmental poisons such as smog.

Developed by a team headed by

Kenneth Castleman, the Automated Light Microscope System (ALMS) is an outgrowth of JPL staff scientist Robert Nathan's work on computer-enhanced X-ray photos. This promising step toward speedy, low-cost chromosome analysis is being funded by the National Institutes of Health with additional support from NASA. Nathan has over-all responsibility as principal investigator for the NIH grant.

Chromosome analysis is currently used to spot hereditary disorders in patients—permitting positive diagnosis of such well-known chromosome disorders as Down's syndrome (mongolism), or the XYY syndrome in which the presence of an extra Y chromosome has been associated with criminal behavior. The clinical practice at present is to photograph chromosomes through a microscope. Each chromosome image is then laboriously cut out of the developed picture by hand, classified visually, and pasted up in groups to form the karyogram. The process takes about 30 minutes.

Under the JPL system, these functions are almost completely automated. An operator watches through closed-circuit TV as the automated microscope searches a slide prepared from a blood

*Without manual or automatic karyotyping, human chromosomes would look like this under a microscope. These chromosomes show several abnormalities resulting from damage due to radiation or chemicals. The top arrow points to a chromosome with three centromeres (the narrow belt-like part that joins the longer strings); normal chromosomes have only one centromere. The other two arrows point to chromosomes without a centromere—an abnormality that occurs when the chromosomes are broken. This photograph was provided by Robert S. Sparkes, MD, a UCLA geneticist who acted as a consultant on the ALMS project.*



## The Automated Light Microscope System is a promising step toward speedy, low-cost chromosome analysis.

sample. He stops scanning when he spots a cell with a good chromosome "spread"—i.e., a group that is spread apart with no overlaps, so that each chromosome is separate and distinct. The system automatically sharpens the focus, enlarges the image 2,500 times, and converts the visual pattern into digital signals for evaluation and manipulation by the computer. The scanning and cell selection functions will eventually be completely automated.

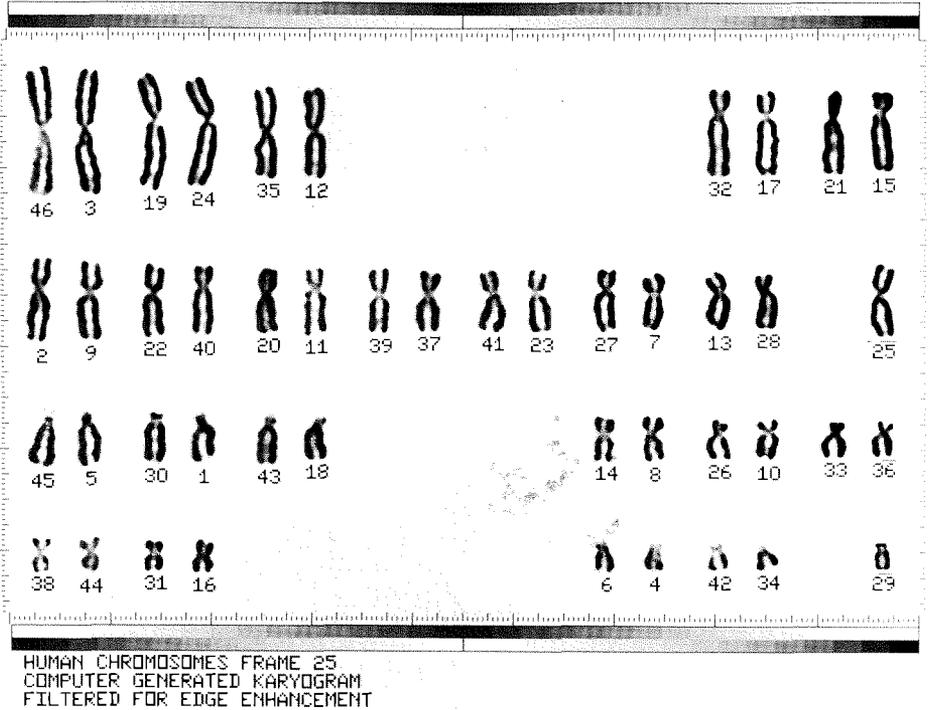
With the chromosome images still in digital code, the computer performs a series of routines that isolate and measure each set of digital values. The coded images are then numbered, classified, paired, and arranged into groups, so that when the digital "picture" inside the computer is translated by a special photographic printer into a visual picture on paper, chromosome images will appear in standard clinical karyotype format.

The entire process takes about three minutes.

ALMS is currently being refined on JPL's large-scale image-processing computer hookup, but it will eventually be structured for a small computer—with a desk-size console—in order to permit clinical applications. At present the system occupies a roomful of equipment, and includes an IBM 1130 utility computer as well as a time-shared IBM 360-44, plus peripheral devices. The 1130 controls the automatic scanning and operates the microscope, and the 360 measures and classifies the chromosomes and generates the output karyogram.

A prototype system utilizing a small computer could be developed in the next year or two. The results of the JPL effort, including design specifications and detail drawings, will become part of the public domain and could lead to commercial production of an economical karyotyping system. At a price of \$50-90,000, such a system would be well within the means of many hospitals and clinical laboratories.

"Our long-range objective," says Castleman, "is a general-purpose automated microscope—one that can automatically analyze not only chromosomes but also blood cells, pap smears, viruses, and other important clinical subjects."



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*The sorting, numbering, and classifying of these chromosomes in a human blood cell, magnified 2,500 times, took just three minutes. The computer that produced this karyogram is the same one that is used to enhance photographs of the Moon and Mars.*