The purpose of these remarks is to present a brief description of some techniques of image processing and to offer a few illustrative examples of the ways in which image processing might contribute to studies of red cell shape. Image processing refers to the application of automatic techniques, both digital and analog, to visual images so as to transform the images or to extract quantitative information from them. While it has been known for some time that one can adequately represent a visual image by a mathematical function, it is only within the past 10-15 years that the electronic technology has made it practicable for images to be translated into numerical form and manipulated by computer programs. A number of working groups [8, 9] have already applied image processing to a variety of problems of biological and medical interest; the applications to health science appear to be particularly attractive and numerous, perhaps because so much life science research depends upon visual inspection of biological objects.

The phrase « image processing » should not be interpreted too narrowly. It is true that most image processing research uses photographs or transparencies as source data, but there is no intrinsic limitation to this input form. While the microscope scanner described below examines the visible light transmitted through the slide, the light source and microscope optics could be changed so as to use ultraviolet light; phase or interference optics could be substituted. More exotic image sources can be and have been used as the basis of image processing; scintillation scanning, ultra-sound and thermography, for example. In fact with images such as those of the scanning electron microscope, the electrical signal ordinarily used to produce an image for human observation can be used directly as the input stream of an image processing system.

Most participants in the technological development of image processing systems for the life sciences have envisioned clinical applications as the (*) This work was supported by the National Institutes of Health under Grants 5 POI GM14940-06 and 1. POI GM19428-01.
goal of their work; differential white cell counting, chromosome karyotyping, PAPANICOLAOU smear screening, etc. Under this motivation image processing is only the first step in a process that must perform some kind of pattern recognition; for example, to classify cells into the five or six common types of leukocytes [4, 10]. Since highly reliable pattern recognition has been found to be a difficult task, a great deal of effort is being devoted to finding features that enable the system to make its classifications agree with those of the medical specialist. The clinicians' criteria are largely empirical and only very indirectly related to the physical or chemical properties of the cell being classified. Furthermore, the engineer's emphasis is on automation; that is, on substituting the system's perceptual judgments for a person's. This is because the machine in clinical use is considered successful (and lucrative to the manufacturer) only if it is a good deal faster at doing what is currently being done by hand.

Ironically, the quantitative measures which can be made most readily by a machine simply cannot be made by the technician with the speed and confidence that he can bring to bear when he is making a perceptual judgment. Measuring a cell diameter, area or eccentricity is very much more difficult for a trained human observer than identifying the type of cell. The importance of quantitative characterization of erythrocytes was recognized more than fifty years ago by PRICE-JONES in his work describing the density distribution of human discocyte diameters [7]. However, the tedium associated with making a large number of measurements by hand must surely have discouraged all but a handful of scientists from using such a direct approach to the problem.

The system described briefly below was developed in order to make

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**FIG. 1.** — Block diagram for CIPG television-microscope scanning system. The teletype block is abbreviated TTY. The Tempo-I computer is manufactured by Tempo computers Inc, 1550 South State College Boulevard, Anaheim, California 92806.