than girls were cyanotic according to the medical histories, and a larger proportion of the boys had low oxygen saturation rates at the time of catheterization. It is clear then that the sex difference in the San Francisco sample does not stem from a greater incidence of cyanosis or oxygen deprivation among the girls.

The second explanatory factor, of a cultural difference in the experience of these children, is more difficult to analyze and evaluate. There is clear evidence in United States samples of normal children that the boys' later I.Q.'s are related to a warm, close relationship to the mother or caretaker in the first years of life (*2*). There is equally clear evidence that the girls' verbal I.Q.'s are negatively related to a too close or an intrusive attitude of the mother to her daughter. These findings would explain the high verbal scores of the boys and low verbal scores of the girls in the San Francisco sample. They would also explain the Mexican results for the girls, since these girls are not overprotected according to Cravioto *et al.* But the results for the Mexican boys do not appear to be in accord with what would be expected unless we take into account a further finding that later or prolonged maternal overprotectiveness (after the first 2 years) is negatively related to the boys' I.Q.'s (*3*). In other words, boys earn relatively high verbal I.Q.'s where there has been a close relationship in infancy with the mother but opportunities to explore later. Girls do best with a friendly, supportive but not an intrusive family situation.

The final question is whether these hypotheses constitute adequate explanations of the findings in the two cultures. We do not think so. The deficit observed in the verbal I.Q.'s of the San Francisco girls who had open heart surgery was highly specific, occurring to a significant degree only where the girls had to recall previously learned material. This may be a chance finding but it was noted in all economic and diagnostic subgroups of the 78 girls who were tested. We would like to know if the patterning of the verbal test scores of the Mexican girls revealed a similar pattern with relatively lower scores on the information and vocabulary subtests. We hope that there will be further reports on sex differences in I.Q. patterning in other samples of cardiopathic children, since there are probably a multiplicity of factors determining these results.

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27 September 1971

Multiple Genotypes in Individuals of Claytonia virginica

The report of variability in chromosome number within individuals of *Claytonia virginica* by Lewis *et al.* (*1*) is an interesting documentation of chromosome behavior in polyploid organisms. They proposed that this variability is under genetic control, and they implied that these "supernumerary" chromosomes may play an adaptive role in the populations where they are found. However, alternative interpretations of these data are possible. Chromosomal behavior can be greatly affected by environmental factors. For example, chromosomes of plants grown under conditions of water stress often display such phenomena as "stickiness" and irregular segregation. If a population of *Claytonia virginica* is in a marginal environment (as was the population studied by Lewis *et al.*), or if individuals are subjected to some sort of "traumatic" treatment (as in this study) that affects their normal functioning, then chromosome behavior may be irregular during both mitosis and meiosis. The result of this behavior would be cells with different chromosome numbers.

Such events are consistent with the data presented by Lewis *et al.*, since the cells with the highest chromosome numbers are in "traumatized" tissue (roots from floral stems) and microsporocytes which would be one of the first groups of cells to feel the effects of drought and one of the last to recover because of an inadequate root system or insufficient water supply. Although the authors reported meiosis to be "largely irregular" perhaps irregularities were not observed in a significant frequency owing to both the small sample size and the relatively high chromosome number.

Thus, there is no reason to assume that chromosomal variability in *Claytonia virginica* is genetically controlled. It is more reasonable to suggest that this variability is environmentally induced, and, inasmuch as the plants are polyploids with a degree of genetic redundancy, the irregular chromosome segregation would have no effect on cellular viability. Earlier, Lewis reported finding individuals of *C. virginica* from the same general locality as the population used in this study with chromosome numbers less than $2n = 28$ (*2*), the lowest number reported in this study. In other words, the "supernumerary" chromosomes offer no selective advantage (they may, in fact, be selectively neutral). The significance of the data of Lewis *et al.* is, in fact, to point out a possible selective advantage of polyploidy in extreme or marginal environments.

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17 July 1971

At least two reasons exist to suggest that chromosomal variability is genetically controlled in *Claytonia virginica*. Primary roots grown in the greenhouse have a high proportion of cells with the common polyploid number ($2n = 28$) even though other parts of the same plants vary by having one to five supernumerary chromosomes. These roots were grown in sterile potting soil, an environment alien to the soil and microorganisms of their native hill in Texas. If trauma and environmental factors have directly affected chromosomal behavior in *C. virginica*, then we need an explanation for the highly consistent chromosome numbers and behavior of mitosis in primary roots.

Data on meiosis are now known in some detail from this population (*1*). "We found over a 5-year period little meiotic irregularity in the microsporocytes excepting during 1970 [16–20 percent]. Most irregularity was simply the absence of pairing for two chromosomes, hardly an abnormal condition, for many cells from the same anther illustrated complete pairing at metaphase I and normal separation at anaphase I." These results based on several hundred plants corroborate the limited data given earlier.

As much as I agree with Parnell that random behavior of chromosomes and environmental stress may indeed be correlated and that polyploids have possible selective advantages in extreme environments, nonrandom distribution of chromosomes during mitosis in primary roots and during meiosis in microsporocytes of plants with supernumerary chromosomes indicates genetic control.

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6 October 1971

Optical Communications

In "Optical communications research progress" (*1*), Miller states, "The scale on which an optical intercity system will become useful is in the range above 500,000 two-way voice channels, or equivalently over 5,000 two-way video telephone channels. . . ." My own estimates indicate that there is a reasonable chance that some form of laser communication system would be competitive with waveguide or coaxial cable systems at about the 1000 channel level by the late 1970's.

As an example, let us consider a system that is based on the helium-neon laser. [Miller dismisses the usefulness of such lasers. He states, "It's main drawbacks are size (20 to 100 cm long) and limited device life."] For geometrical parameters we will use Miller's example of a 100-beam space-multiplexed system guided by 8-inch (20-cm) diameter focusing elements, 100 meters apart, with pulse code modulation repeaters 50 km apart. Then if we wish the total capacity to be 3000 videophone channels (of which 500 would be kept in reserve to allow for component failure), we would need to modulate each beam at 360×10^6 bits per second, well within the laser art. A loss of light of about 1 percent per focusing element and a requirement of 10^4 counted photons per bit (both quite conservative assumptions) implies that each beam would require less than 1 mw of laser power. Thus, we might use 100 helium-neon lasers of 1 mw output at each repeater. Such lasers cost about $300 each, and laser tubes having an 0.8-year lifetime would cost about $25 if they were mass-produced. Thus, the total laser cost over 25 years would be about $100,000 for each 30 (48 km) miles of system. This is only 3 percent of the assumed $100,000 per mile system cost. Since the extra channels would allow much replacement time for laser tubes that failed without the total capacity dropping below 2500 videophone channels and since the lasers would take of a volume perhaps 2 feet (0.6 m) on a side every 30 miles, Miller's objections appear invalid, and the helium-neon laser seems practical.

The cost of the rest of the repeater also seems low enough, even with very conservative assumptions. Each of the 100 repeaters would have circuitry in the same frequency range (360×10^6 bits per second) as television receivers and would be less complex. So a cost of $100,000 per repeater over a 25-year system life seems a conservative estimate. Then if we assume that solid state light detectors and modulators cost $500 each, the total cost of the repeater components, including lasers, would be $300,000, or 10 percent of the cost per mile.

Finally, if each 8-inch focusing mirror costs about $1000 (corresponding to $30,000 per mile) we are left with something on the order of $50,000 per mile for pipe. But this is the approximate per mile cost of a gas pipeline of appropriate (10-inch) diameter.

Space limitations prevent the discussion of (i) the many tradeoffs and auxiliary inventions possible that increase the likelihood that some system should be cost-effective and (ii) a probably superior system based on semiconductor diode lasers, cooled to liquid-nitrogen temperatures. My estimates imply that such a system would be cost-effective even with a transmission medium loss of 22 db/km, such as might be obtained with the use of lenses spaced 1 meter apart or with optical fibers (Miller states categorically that such a loss is too high).

The question might be asked, at this point, why one should believe that my estimates are more realistic than Miller's. I think the answer is that one should not have to believe anyone's estimates. The government should allow total competition to prevail in the manufacture of high-capacity telecommunication systems. Then it would be worthwhile for the rest of the huge (and now underemployed) electronics industry to explore the feasibility of long-distance laser telecommunications. The prospect of multibillion-dollar sales should draw enough venture research now, research that would, in any event, have to be done sometime.

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The situation with respect to the anticipated commercial usage of optical systems in which hard lenses or mirrors are employed remains as reported in the original article. However, advances in the art that have occurred since that article was submitted (April 1970) enhance the possibility of a variety of optical systems in which fibers will be used, including intercity systems with communications capacities smaller than cited in my article. These advances in the art include (i) achievement of research models of gallium-arsenide injection lasers which operate continuously at room temperature, and (ii) realization of single-mode optical fibers with observed transmission losses as small as 20 db/km at 6328 Å wavelength. It is still not possible to anticipate exactly when these improved components will be developed to the point of reproducible manufacture, and the cost competition with coaxial and other systems remains to be accurately evaluated. However, low-loss fibers clearly introduce the possibility of earlier use of optical wavelengths, and a vigorous research exploration is now under way not only at Bell Telephone Laboratories, but also in other companies in England, Japan, and the United States.

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