GENETIC ENGINEERING

1. Since very early times human beings have striven to improve crop plants and domesticated animals by breeding and selection. The discovery of the laws of inheritance by Mendel and the subsequent growth of the science of genetics during the first three decades of this century provided a rational basis for the empirical practices of agriculturists and led to much refinement of experimental procedures. It became possible, for instance, to make fertile hybrids between different species and create new species. Basically, however, animal and plant breeding remained empirical sciences, mainly concerned with generating the most desirable combinations from the existing stocks.

2. In 1927 Muller found that mutations may be produced by X-rays. Subsequently, during the second world war, Auerbach discovered chemical mutagenesis. The artificial induction of novel mutations and the use of these mutations for crop improvement has led to rapid progress in mutation breeding. Powerful sources of irradiation with high energy rays and particles are now available in many breeding stations and large stocks of potentially useful mutants have been raised. Hundreds of new chemical mutagens have been discovered. Some of these are so potent that almost every individual exposed to them may undergo one or more mutations. It is now fairly easy to cause mutations in a particular gene and to select individuals carrying any kind of mutation.

3. During the last fifteen years several major discoveries concerning the chemical basis of heredity have been made. The genes are now known to be made of DNA (deoxyribonucleic acid). The biological attributes of a gene, self duplication, mutation and control of cellular properties can be understood in terms of the structure and chemistry of DNA. This has greatly enlarged the possibilities of experimentally manipulating the genetic apparatus. It is possible, for instance, to design mutagenic treatments which will selectively mutate particular genes.

At the same time our understanding of the mechanisms of genetic exchange has improved greatly. So far breeding has been based exclusively on normal sexual reproduction. It is now known that genes can be transferred from one organism to another in several other ways. Viruses may act as vectors of genes (transduction). Genes may be introduced into a cell by giving it the DNA of another (transformation). These novel systems of genetic exchange have so far been experimentally utilised mainly in microorganisms. They are, however, undoubtedly present in higher organisms, and will be increasingly made use of. A great deal is now known about the genetic code and its operation. Recently Dr. Khorana succeeded in synthesising chemically the first man-made gene. With improved methods it should be possible to synthesise larger genes. It is not at all far fetched to think of ways of introducing artificially synthesised genes into the genetic apparatus of organisms. In fact I believe this will be done fairly soon.

4. All this takes us far beyond the limits of empirical breeding and selection. We may now speak of genetic engineering in much the same sense as mechanical or chemical engineering. An indication of what genetic engineering could do is already available in the case of some of the viruses and bacteria that are used by molecular geneticists as model organisms. The genes of these organisms have been nearly fully mapped. Any of these can be mutated; the mutant gene can be transferred from one organism to another, often of a different genus; the position of the gene on the chromosome can be shifted at will; new genetic elements can be introduced or part of the original genetic material removed from the cell. By such methods organisms have been made that bear little resemblances to their parents and have fantastic properties, often specifically designed to answer some requirement of the experimenter. At present there are difficulties in extending these techniques to higher animals and plants, but in principle the manipulations are of general applicability. I have very little doubt that in not too distant a future (perhaps 20 to 50 years) such a technology will be widely used with higher animals and plants.

5. Will genetic engineering be applied to human beings themselves? This question has several facets. In general all arguments which have been advanced for or against Eugenics are also relevant to genetic engineering with human beings. Partly as a result of the fact that eugenics has been mixed up with racialist doctrines, there

is a tendency among liberal thinkers to under emphasise the relevance of genetic considerations in the evolution of human groups. Planned social development inevitably involves interference with human reproduction either directly through birth control, or indirectly through social and economic measures, which lead to selective breeding. The consequences of such measures are usually felt after a lag of several generations, so that the policy makers pressed by more immediate considerations are likely to ignore these consequences. It seems obviously desirable that long term planning should take into account possible changes in the genetic structure of human population. As to what extent one could actively interfere in order to direct this change is a controversial matter. Apart from possible applications to human population, genetic engineering could be used to cure individual human beings of inherited disorders. At present the possibility is largely theoretical but it is not difficult to imagine that in the next few decades some of the seemingly formidable technical difficulties will be overcome.