HEREDITY: A FACT THAT CAN BE TAMPERED WITH?

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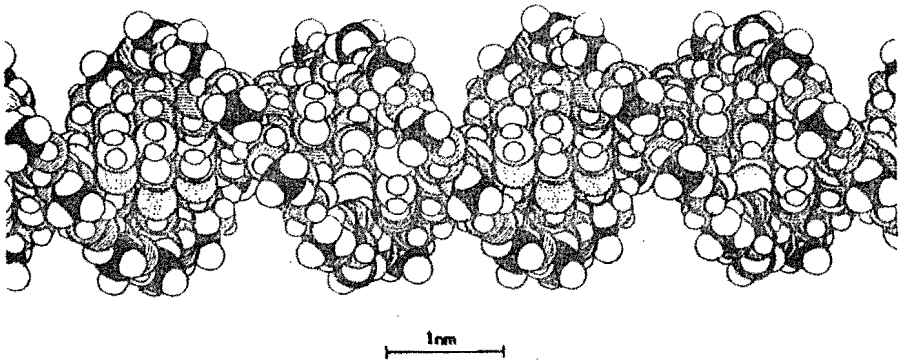
The characteristics of every living organism are the product of the interaction between heredity and the environment. Heredity supplies the individual with a set of characteristics which can be modified to a considerable extent by environmental factors. Rabbits of the Himalayan breed for example develop black pigment at the tips of the nose, tail, feet and ears in the usual range of environments. However, if raised at very high temperatures, an all white rabbit is produced. Also the flowers of hydrangea may be blue if grown in acid soil or pinkish if grown in alkaline soil.

When in 1866 Gregor Mendel published his results after a series of observations on the colour and shape of his garden peas, he laid the foundations of what was going to be the 'core' of the Modern Biological Sciences. Mendel knew nothing about chromosome and meiosis, a form of nuclear division that halves the chromosome number, yet he depicted that a plant with 2 factors, (or genes), one for round shaped peas, the other for wrinkled shaped peas would only transmit one of these factors through a gamete to its offspring. He also stated that the segregation of one factor pair was independent of the segregation of another factor pair. The significance of Mendel's results was not realised until their rediscovery in 1900, and in 1903 Sutton suggested that hereditary factors or genes were carried on chro-



The double-helical DNA molecule formed by intertwining of two DNA chains of complementary base sequence. (*From* Feughelman *et al.*, 1955.)

mosomes. This hypothesis was confirmed later by Morgan while working on the chromosomes of the fruit-fly, Drosophila. The chromosomes, which are found in the nucleus of the cell, have distinct staining properties. In fact, in 1924, Feulgen developed a stain which has shown the presence of the deoxyribose form of nucleic acid (DNA) in the chromosomes. The DNA, which consists of phosphoric acid, a pentose sugar and nitrogenous bases, form in conjunction with a protein matrix the material of the chromosome. The DNA molecule has the capacity for self-replication, its stability being an important factor in its passing intact from parent to offspring. On rare occasions, however, a change in the DNA molecule may arise spontaneously. This is known as a mutation and may result in a defective protein or the complete absence of a protein. The net result is often a change in the the organism or a change in some character or trait of the organism. Healthy people have a gene that specifies the protein structure of the red blood cell pigment called haemoglobin. A mutation may arise in this gene that gives rise to a defective haemoglobin protein. This is the case with some anaemic individuals, where as a result of this gene mutation, the defective haemoglobin is unable to carry the right amount of oxygen to the body cells.

Besides the gene mutations, there can also be chromosomal mutations. Breaks can occur in the chromosomes, and chromosomal material may be lost or displaced. This means lost or displaced genes and if the mutation occurs in the germ cells and is transmitted from the parent to the offspring, a phenotypically changed (abnormal) offspring may result.

Mutations, which may thus be defined as heritable alterations in the genotype, may also be induced. Ionizing radiations, ultra violet light and certain chemicals induce mutations and are known as mutagenic agents. In 1927, Muller demonstrated that X rays could induce mutations in Drosophila. A year later Stadler proved the mutagenic effect of X rays on barley. Since that time X rays have been used to induce a large number of mutations in many organisms. These mutants have served as landmarks that could be followed from one generation to the next in the transmission of genetic material. Also, with the awareness of the harm that can be induced by ionizing radiations in living organisms, more care is being taken about the use of X rays and in particular about the doses used.

Organisms belonging to a particular species have got a specific number of chromosomes per cell. Thus in normal human beings there are 46 chromosomes in each cell, these being found as 23 pairs of homologous chromosomes. Each pair of chromosomes have identical genes (or their mutant forms) located at corresponding loci.

In the dog's cell the number of chromosomes is 78, while in the cat's it is 38. This is referred to as the diploid number of chromosomes. During gametogenesis, that is during the formation of the egg and sperm in animals or ovule and pollen grain in plants, the chromosomal number is halved by the reduction division known as meiosis, so that each gamete will contain the haploid number of chromosomes. This

means that each human gamete (egg or sperm) will have 23 chromosomes. When fertilization takes place and fusion of the gametes results, the new zygotic cell that is formed and that will give rise to a new individual will have again 46 chromosomes.

A mutation may also involve a change in the chromosmal number. Thus an individual may posses one or more sets of homologous chromosomes in excess of the normal diploid set and in this case it is referred to as a polyploid organism. The normal tomato plant has 24 chromosomes in each cell, whereas a polyploid tomato plant would contain 36 or 48 or even more chromosomes per cell.

In some cases, instead of having one or more sets of chromosomes being added to the normal diploid number, there may be the addition (or loss) of just one or more chromosomes, a phenomenon that is known as aneuploidy. Thus, the mongol is an aneuploid individual with 47 instead of the normal 46 chromosomes per cell. An extra chromosome labelled number 21 gives rise to a set of abnormalities which are referred to collectively as Down's syndrome.

Once it was thought that polyploidy was quite common in plant species. However, we now know that it is quite rare in natural populations. In modern plant breeding, polyploids are being artificially induced by an alkaloid drug known as colchicine. This method of inducing polyploidy artificially is important in obtaining new agricultural and horticultural varieties. Polyploid plants are in general larger than their related diploids, this being due to an increase in cell size. In fact there is an increase of various plant parts, including an increase in the size of the flowers and fruits which makes polyploids commercially important.

Much of the emphasis in plant breeding has been on increasing agricultural productivity. This will be accomplished not only by the breeding of higher yielding varieties but also by the development of varieties that stabilize production through resistance to disease, drought, heat, cold and wind. Mendelian diversity arises through gene mutations that are very essential for evolution to take place. Sometimes a single mutation may enhance the usefulness of a species to man. Cauliflower, Brussels sprouts and Kohlrabi have all been derived from the wild cabbage. The great morphological differences between the cultivated types and the wild type are due to a few gene differences.

Another method of evolution of cultivated plants depends on the crossing of distinct species with the preservation of improved types from the products. When distinct species are crossed, the offspring, if any, tends towards a high grade of sterility. In order to preserve the vigour which characterizes many such interspecific hybrids, vegetative propagation, such as budding or grafting, has to be used. Certain varieties of pears, plums, cherries, and grapes have arisen from interspecific hybridization, as have many flowers such as certain irises, roses, lilies and rhododendrons.

Organisms showing advantageous characteristics are usually favoured by artificial selection both in plant and animal breeding. Very often, inbreeding, which is the mating of close-

ly related individuals such as self-pollination in plants or brother-sister matings in animals is employed. By this method, advantageous characteristics will be preserved. However, there is a great probability that recessive (or hidden) traits, many of which are deleterious, will begin to appear. In fact, one of the consequences of inbreeding is a loss in vigour. This can be seen quite clearly in some pure breeds of dogs. Dog breeders very often favour certain characteristics in a particular breed which they try to preserve as much as possible by inbreeding. The result is that many dogs win prizes in dog shows, but are otherwise weakened physically and rendered less resistant to some diseases.

A remedy for this 'inbreeding depression', both in animals and plants, is to cross distinct inbred lines. These crosses usually produce a vigorous hybrid generation. This hybrid vigour, such as increased size, fecundity, or resistance to disease is known as heterosis and even species that seem to show little or no harmful effects from inbreeding, frequently benefit from such crossing.

The study of genetics has opened wide horizons in the study of life and with the development of plant and animal tissue and cell culture techniques new perspectives have arisen. There is still much to be done in this field and the big question is whether through a better understanding and better use of the hereditary mechanism, some of the major problems in the world, including the seemingly inadequate food supply and a large number of hereditary diseases, will be solved.

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